

**STOCK MARKET INTEGRATION
AND DUALY LISTED STOCKS:
INDIAN ADR AND DOMESTIC STOCK PRICES**

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Abstract

In search of the micro-foundation of the commonly held view of a dominant Nasdaq and satellite Bombay Stock Exchange (BSE), the study looks into the price interdependence of ten Indian companies, which have floated American Depository Receipts (ADRs). The strong correlation between the prices of the dually listed stocks is corroborated by the finding of a bi-directional causality in a vector autoregression model. The competing domestic stock exchange, *viz.*, National Stock Exchange (NSE) too is found to share the same bi-directional relation scrip-wise with the Nasdaq / New York Stock Exchange. Furthermore, the impulse responses pattern indicate that a positive shock in the domestic (international) price of a scrip gets transmitted in terms of a strong positive movement in the international (domestic) price the very next day. Thus, the quotes of both the markets share not only a stock-wise bi-directional causality but markets also are efficient in processing and incorporating the pricing information.

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STOCK MARKET INTEGRATION AND DUALY LISTED STOCKS: INDIAN ADR AND DOMESTIC STOCK PRICES

1. Introduction

The financial markets in general and the equity market in particular have now become more closely interlinked the world over than ever before despite the differences in risk perceptions of the markets or the country profiles. The dynamics of cross-country trade and payments have evolved to such an extent that the economic slowdown of a country is bound to affect its trading partners as clearly discernable from the leading movement in the global stock prices. The close integration between the emerging and the developed markets has even led to sentiment spillover from one market to another.¹ A possible contributor to the similar volatility profile across the markets is the listing of stocks at dual or multiple stock exchanges all over the globe (Bennett and Keller, 1988). Their movement in tandem powered by the instinct of arbitrage could have contributed to the emergent cross-country co-movement of stock prices.

With the financial sector reforms initiated in 1991, Indian stock market has since joined the integration process. The inflow of foreign funds with entry of foreign institutional investors (FII) has transformed the style of functioning of the Indian stock market. Moreover, it has forged an important linkage between the capital and the forex markets. During this phase, investment norms for non-resident Indians (NRIs), persons of Indian origin (PIOs) and overseas corporate bodies (OCBs) have been largely liberalized, *inter alia*, with permission to purchase of shares without any prior approval from the RBI. Further, the Indian corporates have been allowed to tap the global market with global depository receipt (GDR), American depository receipt (ADR) and foreign currency convertible bond (FCCB) since 1993.² On the other hand, the world-class facilities provided by the newly constituted National Stock Exchange (NSE) have unleashed competitive forces, prompting other exchanges to go for automation and screen based trading. All these have ushered in an era of integration and globalization of the hitherto insulated and segmented Indian stock market.

The globalisation of the Indian stock market is reflected in catching up with the best international practices, *inter alia*, dematerialisation of shares, replacement of the Indian carry forward trading system called *badla* by the index-based and scrip-based futures and options; rolling settlement in place of the account period settlement; internet trading and so on and so forth. More significantly, the domestic market movement has come to be largely determined by the undercurrent of the global markets in general and the Nasdaq in particular. This was reflected in an increase in correlation coefficient of the indices of Indian stock market with those in the developed countries. Year wise during 1994-97, correlation coefficient between the BSE Sensex and the Nasdaq Composite Index has even been negative. It has since started turning positive from 1997-98 and remained significantly positive during the latest three year period 1999-2002.

The co-movement of the Indian stock market with the Nasdaq has evinced considerable interest and evoked contesting hypotheses behind the market phenomenon (e.g., Shah, 1999; Hansda & Ray, 2002). Besides, the likely outcome of co-movement of markets remains contentious in regard to its impact on the cost of capital or the feedback on the integration process itself. Indeed, there has been explicit concern that the movement of markets in rhythm and chorus could nullify much of the gain out of diversification across borders, besides being vulnerable to the caprices of global capital. On the other hand, there seems to be a general consensus on the satellite position of the Indian stock market vis-à-vis the global market. Such a proposition possibly emanates from an analysis of the market movement in a framework of

overall or sectoral indices. And not surprisingly, given the limited magnitude and dimension of the Indian stock market, the Nasdaq stands out the dominant leader with an overbearing influence. Such macro approach to stock market analysis however camouflages the micro behaviour of individual stocks, keeping the micro-foundation of macro pronouncements all the more tenuous. The present study aims at filling up such gaps, unraveling the nuances and dynamics of the individual stock behaviour at the domestic as well as the international exchange as also their inter-relationship. Keeping in view the importance of the US stock market in terms of its ramifications for the Indian economy in general and the domestic stock prices in particular, the focus of the present study has been the price behaviour of the Indian ADRs listed in Nasdaq/NYSE (i.e., New York Stock Exchange) rather than the Indian GDRs. Indeed, the US has recently emerged as the marketplace for trading of even the Indian GDRs through the PORTAL system.

Specifically, the present study is built around the following quests. Does the domestic price behaviour of a dually listed Indian stock impact its ADR price and vice versa? Does the dominant-satellite relationship between the Nasdaq and the Indian stock market hold good even at the level of individual stock? Does the transmission of pricing information of individual stocks across the US and the Indian markets reflect the efficiency of the markets? How does a price shock in one market get transmitted to the other market? How long does the shock persist? The present paper looks at some such questions in the Indian scenario in the context of price behaviour of dually listed stocks.

The rest of the study is organized as follows. While section 2 traces the genesis and regulatory set-up for the DR issue by an Indian company, section 3 presents a select survey of literature on the price interdependence of the stock markets with special emphasis on the dually listed stocks. Section 4 discusses some stylized facts on the price behaviour of select scrips on the BSE and its ADR counterpart on the Nasdaq / NYSE. Against a methodological backdrop, section 5 provides the empirical evidence on causality between the dually listed stocks, and examines the tenability of the dominant-satellite hypothesis at the micro level. With a methodological flavour, section 6 presents the empirical evidence on efficiency in transmitting the pricing information across markets. Section 7 summarizes the study providing a direction for future research.

2. Genesis of Depository Receipts: The Indian Experience

Starting with the maiden issue of the Reliance Industries in May 1992, around 81-odd Indian companies have so far tapped the global market with a cumulative mobilization of Rs. 37,417.35 crore by the end of 2001-02 through 115 issues (Table 1). Indeed, India has the distinction of issuing the maximum number of DRs among the emerging economies. The genesis of Indian multinational corporations (MNCs) with not only international operations but also a global ownership is a logical fallout of this process.

While bunching of DR issues took place in the early 1990s possibly in view of the pent-up overseas demand for Indian papers, it seemed to have been primarily motivated by the existing costly procedure of floatation in the domestic market (Patil, 1994). Initially GDR was the preferred mode with the majority of listings in the Luxembourg or the London Stock Exchange in view of their less stringent disclosure requirements vis-à-vis the requirements under the US GAAP (i.e., Generally Accepted Accounting Principle). Besides, a majority of the Indian GDRs were issued pursuant to the US Rule 144A and/or Regulation S of the Securities Exchange Commission, which enabled their trading in the US market too mainly through the PORTAL system. Nevertheless, ADR has since emerged as the star attraction thanks to its higher global visibility, particularly for the new-economy stocks, with nine issues listed in NYSE and three issues in Nasdaq so far (Table 2). While the ownership pattern of Indian

GDR/ADR is not clear, both individual and foreign ownerships were in general found to be higher in London than in the US as per the Paris-based World Federation of Exchanges (FIBV) Survey (1999).

Table 1: Euro Issue by Indian Companies
(Amount in Rs. crore)

Item	Amount Raised	No. of Euro Issues
1	2	3
1992-93	702.32	2
1993-94	7,897.82	27
1994-95	6,743.23	31
1995-96	1,296.69	5
1996-97	5,594.27	16
1997-98	4,009.46	7
1998-99	1,147.78	3
1999-00	3,487.21	6
2000-01	4197.07	13
2001-02	2341.50	5
Total	37,417.35	115

Source: *Handbook of Statistics on Indian Economy*, RBI, various issues.

Table 2: ADR Issue by Indian Companies

Company	Issue Day	Stock Exchange	Lead Manager	Offer Price (\$)	Amount Mobilised (\$ million)	ADR: Domestic Share
1	2	3	4	5	6	7
1 Infosys	11 March 1999	Nasdaq	BT Alex Brown	55.7	70.4	2:1
2 Satyam Infoway	19 Oct 1999	Nasdaq	DSP Marill Lynch	n.a	150.0	1:2
3 Rediff.com India	13 June 2000	Nasdaq	Goldman Sachs	12.0	55.2	2:1
4 ICICI	22 Sept 1999	NYSE	DSP Marill Lynch	9.8	275.0	1:5
5 ICICI Bank	28 March 2000	NYSE	DSP Marill Lynch	11.0	175.0	1:2
6 Silverline	20 June 2000	NYSE	Saloman Smith Barney	25.0	130.0	1:2
7 VSNL	15 August 2000	NYSE	Saloman Smith Barney	11.0	n.a.	1:2
8 Wipro	19 Oct 2000	NYSE	Morgan Stanley	41.4	135	1:1
9 Dr. Reddy's	11 April 2001	NYSE	Marill Lynch	10.1	Rs. 619.1 cr	1:1
10 Satyam Computers	15 May 2001	NYSE	Marill Lynch	9.7	140.0	1:2
11 HDFC Bank	20 July 2001	NYSE	Marill Lynch	13.8	172.5	1:3
12 MTNL	28 Sept 2001	NYSE	Goldman Sachs	5.9	n.a	1:2

Sources: (1) *Monthly Review of Indian Economy*, Centre for Monitoring Indian Economy, various issues.
(2) Bank of New York (<http://www.adny.com>)
(3) Instanex Capital (<http://www.instanex.com>)

Initially, companies seeking to float DRs were required to obtain prior permission from the Department of Economic Affairs, Ministry of Finance, the Government of India (GOI). To be eligible, companies should have a consistent track record of good performance for a minimum period of 3 years. The infrastructure companies were exempted from the latter requirement in June 1996. The restrictions on number of DR issues were also removed in June 1996. The Euro issue proceeds were subject to a number of end-use restrictions modified from time to time before their withdrawal in May 1998. However, such proceeds were not to be invested in stock market and real estate. In December 1999 Indian software companies, in March 2000 other knowledge-based companies, and in April 2001 all types of companies were permitted to undertake overseas business acquisition through ADR/GDR stock swap. In January 2000, companies were made free to access the GDR/ADR market through an automatic route operated by the RBI, without the prior approval of the GOI or the track record condition. The issuing company needs to furnish full particulars of the issue to the GOI and the RBI within 30 days of completion of such transactions. Similarly companies were allowed in phases

to utilize, without any prior approval, part of the DR proceeds for overseas investment and finally upto 100 per cent of the proceeds from February 2001.

DRs can be redeemed at the price of the corresponding shares of the issuing company ruling on the BSE or the NSE on the date of redemption. Similar norms apply to conversion of FCCBs. The ordinary shares and FCCBs issued against the DRs are treated as foreign direct investment (FDI). The aggregate of foreign equity participation directly or indirectly through the DR mechanism should not exceed 51 per cent of the issued and subscribed capital of the issuing company. Two-way fungibility in DR issues of Indian companies has been introduced from February 13, 2002 whereby converted local shares could be reconverted into DR subject to sectoral caps on FDI.

Interest payment and dividend on these instruments are subject to tax deduction at source at the rate of 10 per cent. Capital gains on account of transactions among non-resident investors outside India are free from any income tax liability in India. However, transfer of the aforesaid shares in India to the non-resident investor is liable to income tax at the rate of 10 per cent. Holding of DRs by non-resident investors, holding of underlying shares by ODB in a fiduciary capacity and transfer of DRs between non-resident investors and ODB are exempted from wealth tax and gift tax. Provisions of avoidance of double taxation agreement (entered into by the GOI with the country of residence of the ODB) are applicable to the DRs.

There are two alternative, albeit not mutually exclusive, ways of investment in Indian shares by a foreign concern. As an FII registered with the SEBI, it can directly participate in trading and investment in the Indian stock market. Alongside or alternatively, it can buy DRs of the Indian companies in the overseas markets. Given the legal and institutional requirements as also the tax implications for an FII, small and medium sized investors and particularly foreign individuals might find it convenient to invest in the Indian GDR/ADR rather than in the Indian market *per se*. While virtual capital account convertibility for the non-residents has provided such alternative avenues of investment, its absence for the resident citizens of India has confined them to the domestic market. Indian fund managers including mutual funds are, however, now permitted to invest in ADR/GDR of Indian companies, and foreign debt securities upto 4 per cent of their net assets subject to a maximum of \$50 million per mutual fund and \$500 million for the overall industry.

3. Interdependence of Stock Prices and Dually Listed Stocks: A Survey of Literature

The merits of international diversification in containing the systematic risk is long recognised in the literature with one of the earliest attempts by Grubel (1968). Initial studies in this direction focused upon the inter-dependence of the national equity markets. The reported low or statistically insignificant correlations of stock returns across the countries pointed to the determining role of the domestic factors as also the scope for international diversification (e.g., Lessard, 1973). The global crash of October 1987 stimulated worldwide interest in this line of study. For example, Bennet and Keller (1988) brought out evidence of strong international equity market linkages. The US market was found to have the greatest influence on all other markets (e.g., Becker *et al.*, 1990). Such inter-linkages however put a limit on the gains out of international diversification.

While a number of hypotheses were put forward to explain the interdependence of stock returns, Heston and Rouwenhorst (1994) attributed their interdependence to four factors: global business cycle, global industry factor, country specific factor and firm level effect. Out

of the four, the global industry effect was considered the most important with the globalisation and the new economy (Hobijin and Jovanovic, 2000).

In the Indian context, Ignatius (1992) compared returns on the BSE Sensex with those on the NYSE S&P 500 Index. He, however, did not find any evidence in favour of integration. Similar view was expressed by Agarwal (2000) on the basis of average correlation coefficient of 0.01 between India and the developed markets. In a study across 21 developed and 19 emerging countries including India, Brooks and Catao (2000) found evidence of stock market integration during March 1986 through August 2000, operating through the channel of information technology (IT) industry. In a recent study for 1999-2000 through 2000-01, Hansda and Ray (2002) observed a unidirectional causality from Nasdaq to BSE or NSE. The relation as well as direction of causation held good for the technology segment of the NYSE and BSE or NSE. However, domestic prices of technology stocks and overall domestic share prices were found to be independent of each other.

A major limitation of all these studies is their aggregative nature and analysis in terms of overall or sectoral indices to the neglect of individual stocks. With the globalisation of the stock markets worldwide, dual or multiple listing of stocks across the globe has emerged as the latest trend. International listing was expected to contain the negative impact of stock market segmentation and lead to an increase in domestic share prices. However, Amihud and Mendelson (1995) expressed concern of a fragmented trading volume following a multiple listing. Domowitz *et al* (1998) felt that the increasing number of DRs from the emerging countries could even inhibit the development of their domestic equity markets as the latter might be left with only small and illiquid stocks. The advocates of multi-market trading such as Hamilton (1979), and Chowdhry and Nanda (1991), however, believed that intensified competition among the exchanges might outweigh any negative externalities associated with the multi-market trading.

Another set of studies on multi-market trading was directed towards tracking the liquidity of the underlying stocks, believed to be increasing with international listing and reflected in a narrowing bid-ask spread (e.g., Mittoo, 1992). Noronha *et al* (1996) however observed a phenomenon to the contrary in the case of American stocks listed on the London and Tokyo Exchanges. On an examination of 25 Mexican ADRs, Domowitz *et al* (1998) found evidence of a declining spread for the unrestricted domestic shares and no measurable liquidity effect on the restricted domestic shares. In the Indian context, Kumar and Saudagaran (2001), on the basis of a sample of 30 Indian DR programmes between January 1, 1996 and June 30, 2001, reported that GDR listing in general increased the liquidity of the underlying domestic stocks while ADR listing in most cases reduced their liquidity. The stringent disclosure requirements for ADR leading to a possible fragmentation of trading as against order flow migration of Indian GDR to the Indian exchanges in view of one-way fungibility of DRs, and the ADR listing in a receding Indian market as against the GDR listing in a surging Indian market were cited as the possible reasons for the differing impacts on liquidity.

A number of studies on international listing concentrated on the domestic share price movements around the day of foreign listing (e.g., Alexander *et al*, 1988). With increased liquidity and volume, volatility was expected to decline *a priori* following a multi-market listing (Domowitz *et al*, 1997). Here the impact of cross listing for the developed and the emerging markets seemed to be varying. Jayaraman *et al* (1993) suggested of a permanent increase in volatility for the ADRs from the developed countries. After all, cross-listing possibly led to more disclosures, which, in turn, could have contributed to the increased variance of the domestic stock prices. On the other hand, listing of ADRs was associated with a reduced volatility of the underlying Mexican stocks (Domowitz *et al*, 1997). Howe and Madura (1990), however, reported negligible impact on the risk profile of the American stocks following the international listings. The extent of abnormal return to the underlying domestic

stock around the issue of Indian GDR declined comparatively after May 15, 1994 as per Shah (1995).

A relatively unexplored area has been the transfer of pricing information between the foreign and the domestic stock exchanges through the international listing. Garbade and Silber (1979) investigated the dominant-satellite relationship between the exchanges in terms of information formation and transmission. Neumark *et al* (1991) found for the cross-listed US stocks that the price volatility in foreign exchanges fully reflected the domestic price movement in the US and only to a lesser extent the other way round. Similarly, the domestic market of Israel turned out to be the dominant one for the Israel ADRs vis-à-vis the foreign market of the US (Lieberman *et al*, 1999). On the other hand, Lau and Diltz (1994) and Bae *et al* (1999) found evidence of transmission of pricing information in both directions between New York and Tokyo, and Hong Kong and London respectively. Kim *et al* (2000) observed that while the underlying share price was most important for the price movement of ADRs issued by 5 developed countries, the exchange rate and the US market also had their impact. In general, transmission of the pricing information was indicative of the efficiency of domestic and ADR markets as abnormal returns could not be earned from any price dependence (Rosenthal, 1983). A lagged price response between the shares listed in Hong Kong and London, observed by Bae *et al* (1999), was not however consistent with the efficiency hypothesis. Nevertheless, dual listing in general did not give rise to arbitrage opportunities (Bae *et al*, 1999, and Lieberman *et al*, 1999). On the other hand, Foerster and Karolyi (1999) found that the non-US firms issuing ADRs earned cumulative abnormal returns during the year before listing, an additional return during the listing week and finally incurred losses during the year following listing. Such events were taken to be the fallout of market segmentation. In the Indian context, a persisting premium on the Indian GDRs extended credence to the market segmentation hypothesis (Jithendranathan *et al*, 2000). The Indian GDR index returns were found to be affected by both domestic and international factors while the underlying Indian shares were influenced only by domestic variables.

4. Trends in Prices of Indian ADRs and Their Domestic Counterparts

What is the relationship between prices of ADRs of the Indian companies, and those of their domestic scrips? Towards this end, prices of the dually listed stocks have been plotted in a scatter (Graph 1).³ The exercise, however, remains limited to 10 stocks as Satyam Infoway and Rediff.com India are not domestically listed on the BSE or the NSE. For the purpose of scatter, the ADR prices in US \$ have been converted into Indian Rupees by using the ruling US \$-Rupee exchange rate. As ADRs are equivalent of a multiple or a fraction of domestic stocks, the ADR price per share denominated in Rupees has been compared with the corresponding domestic price per share.⁴ As is clear from Graph 1, the open price at BSE and the close price with one day lag at Nasdaq / NYSE are found to be closely tracking each other for all the stocks barring the ones for VSNL and HDFC Bank. Even for VSNL, price differentials are broadly maintained over time. The price behaviours of HDFC Bank, however, do not seem to be in close alignment with each other. In general, the exchange rate adjusted ADR price per share has been ruling at a premium over the corresponding underlying domestic price per share. A similar pattern is noticed on the same day between the close price at BSE and the open price at Nasdaq / NYSE (Graph 2). On the whole, the scatter has thrown up preliminary indications of a possible underlying relation between the prices of the dually listed Indian stocks.

In order to look into the possibilities of arbitrage on a real time basis, a digression on the timing of trading in the two sets of Stock Exchanges, *viz.*, domestic and foreign would be in order. The typical trading session in India commences at IST 10:00 AM and continues till IST 4:00 PM whereas the trading session in the US starts at IST 8:00 PM on the same day and closes at IST 2:30 A.M on the next day, much ahead of the Indian trading session the following

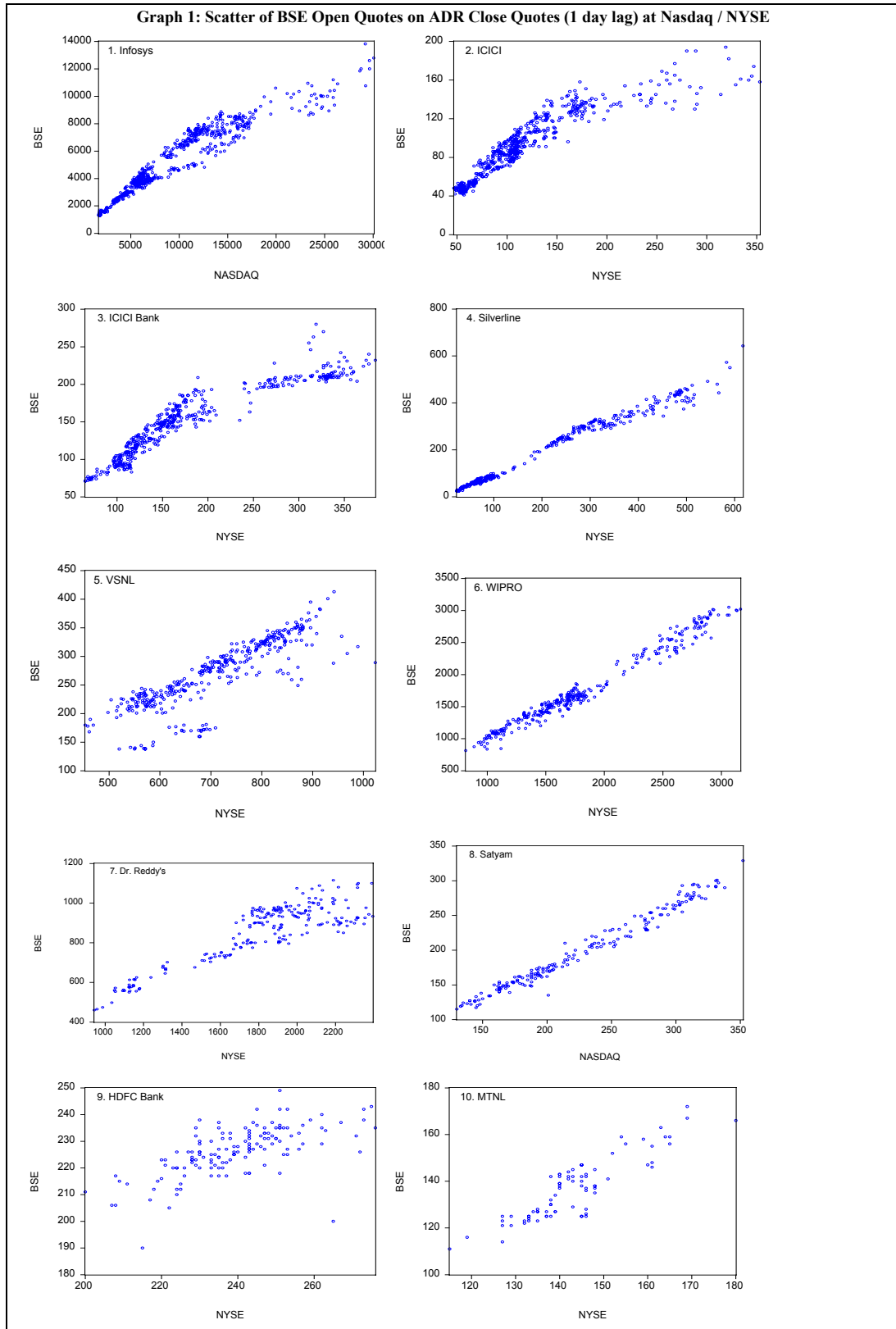
day. As a result, arbitrage across the markets cannot be carried out on a real time basis (Table 3).

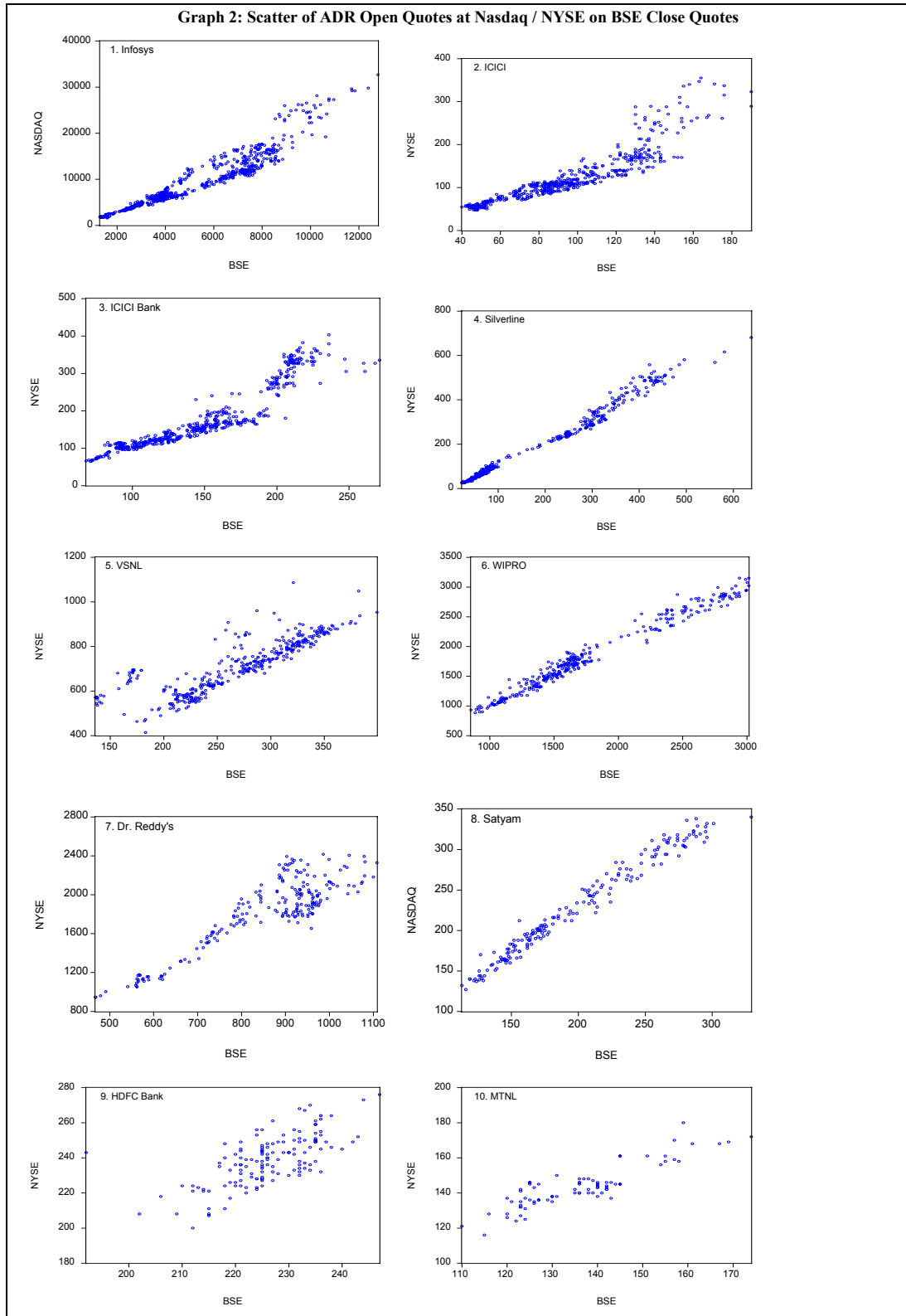
Table 3: Typical Trading Sessions of BSE / NSE and Nasdaq / NYSE
(Times in Indian Standard Time)

Day T		Day T+1	
BSE / NSE Opens	BSE / NSE Closes	Nasdaq / NYSE Opens	Nasdaq / NYSE Closes
↓	↓	↓	↓
10:00 hrs	16:00 hrs	20:00 hrs	2:30 hrs

The observed synchronised movement between the Indian and foreign stock prices is corroborated by a very high and positive coefficient of correlation largely hovering around 0.9 for the ADR price and the corresponding domestic share price (Appendix Tables 1 & 2). This is true for any combination of price (open or close), stock (any of the 10 stocks listed as ADR), domestic stock exchange (BSE or NSE) and foreign stock exchange (Nasdaq or NYSE). The strength of coefficient of correlation remains unaltered whether one carries out the exercise with chronologically contemporaneous data or chronologically one day lagged data only for the foreign stock exchange keeping in view the non-synchronous trading sessions of the two countries on a real time basis (Appendix Tables 3 & 4).

The magnitude of correlation coefficient on the basis of level variables remains broadly the same for various permutations and combinations of prices – open-open, close-close, close-open, or open-close in respect of domestic and foreign stock exchanges.⁵ As is widely expected, the close price of a stock on an exchange has turned out to be in a close co-movement with the open price of the same stock on the other exchange, given the non-synchronous trading sessions for India and the US. In course of the day however, the high tide of influence of the close price on the price behaviour in the other exchange tends to ebb away under a confluence of myriads of cross-currents – stock exchange-specific or otherwise. As a result, co-movement of close to close or open to open prices has not been so strong as in the case of open to close or close to open prices between the domestic and foreign stock exchanges. The following section presents a rigorous test of the strength of such relationship in a framework of causality.





5. Causality Patterns between the Dually Listed Stocks: The Empirical Evidence

5.1 Methodology

The strong co-movement of ADRs with the underlying domestic shares should not be construed as coterminous with causality. The synchronised co-movement could even be a fall out of spurious relationship. In order to steer clear of such misgivings, the popular causality test *a la* Granger (1969) has been applied to the ADR price and the corresponding domestic stock price. To put it simply, a variable X is said to *Granger cause* another variable Y, if present values of Y can be predicted with better accuracy by using past values of X rather than by not doing so, other information being identical. Formally, Y *fails to Granger cause* X, if for all $s > 0$, the mean square error (MSE) of a forecast of X_{t+s} based on (X_t, X_{t-1}, \dots) is the same as the MSE of a forecast of X_{t+s} that uses both (X_t, X_{t-1}, \dots) as well as (Y_t, Y_{t-1}, \dots) . Thus, the notion of Granger causality has no ontological connotation; rather it is a concept of incremental predictability in a vector auto-regression (VAR) model.

Before applying the causality test, time series properties of the stock prices have been checked by conducting the Dickey Fuller Test of stationarity. As is clear from the DF test statistics, all the stock price series are non-stationary in levels (Appendix Table 5). However, their first differences turn out to be stationary. Therefore, the causality exercise between the scrip-wise prices – domestic and foreign – has been carried out in a framework of unrestricted reduced form vector autoregression (VAR) in first difference variables, addressing the concern of a non-stationary stock price series: $\Delta \mathbf{X}_t = \mathbf{B}_0 + \mathbf{C}(L) \Delta \mathbf{X}_{t-1}$, where, \mathbf{X} is the vector of stock prices (domestic and foreign) variables, and $\mathbf{C}(L)$ is the lagged polynomial operator of order N, *i.e.*, $\mathbf{C}(L) = 1+L+L^2+ \dots + L^N$, with $L^k \mathbf{X}_t = \mathbf{X}_{t-k}$.⁶

As the chosen lag length has turned out to be uniformly one on the basis of Akaike's Information Criterion (AIC), the discussion in rest of the paper is in terms of the following two distinct sets of company-specific VARs:

$$\begin{bmatrix} \Delta P_t^{F,C}(i) \\ \Delta P_t^{D,O}(i) \end{bmatrix} = \begin{bmatrix} a_{10}(i) \\ a_{20}(i) \end{bmatrix} + \begin{bmatrix} a_{11}(i) & a_{21}(i) \\ a_{12}(i) & a_{22}(i) \end{bmatrix} \begin{bmatrix} \Delta P_{t-1}^{F,C}(i) \\ \Delta P_{t-1}^{D,O}(i) \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t}(i) \\ \varepsilon_{2t}(i) \end{bmatrix} \quad (VAR1)$$

$$\begin{bmatrix} \Delta P_t^{D,C}(i) \\ \Delta P_t^{F,O}(i) \end{bmatrix} = \begin{bmatrix} a'_{10}(i) \\ a'_{20}(i) \end{bmatrix} + \begin{bmatrix} a'_{11}(i) & a'_{21}(i) \\ a'_{12}(i) & a'_{22}(i) \end{bmatrix} \begin{bmatrix} \Delta P_{t-1}^{D,C}(i) \\ \Delta P_{t-1}^{F,O}(i) \end{bmatrix} + \begin{bmatrix} \varepsilon'_{1t}(i) \\ \varepsilon'_{2t}(i) \end{bmatrix} \quad (VAR2)$$

where superscripts F and D refer to the quotes at foreign and domestic stock exchanges, superscripts C and O refer to the close and open quotes, and i refers to the company (for i = 1 to 10).

5.2 Granger Causality Patterns

The exercise has been applied to 10 stocks listed in both the BSE and the Nasdaq / NYSE in the context of VAR 1 and VAR 2. The exercise has been carried out scrip-wise on daily share prices covering the scrip-specific first day of ADR trading through the end of February 2002. The period of the study has not been extended further in view of the major policy change on DR, ensuring its two-way fungibility from February 13, 2002. The test of causality has been carried out with a composite null hypothesis. The basic null hypothesis put to test in the study runs as follows: the scrip-wise ADR price (close) does not cause its corresponding domestic share price at BSE (open). Simultaneously, tenability of yet another

null hypothesis that the domestic share price at BSE (close) does not cause its corresponding ADR price (open) has been examined.

Granger’s F Statistics for the first null hypothesis that the ADR price (close) does not cause the domestic share price at BSE (open) are reported in Table 4. Clearly, the close quote of ADR at the Nasdaq / NYSE has emerged to Granger cause the open quote at the BSE for all the companies. In other words, the macro relation of a dominant Nasdaq/NYSE and satellite BSE seems to hold good even at the micro level. Such observation at the individual scrip level could be a fall-out of order flow migration from the Nasdaq/NYSE to the BSE driven by the instinct of arbitrage in the context of one way fungibility of ADRs into domestic shares. However, persistence of premium on the Indian ADRs in relation to their domestic counterparts tends to take away the fire from the argument even though the case for intermittent arbitrage tapping the transient movement in market could not be ruled out whenever the Indian ADRs traded at a discount to their domestic counterparts. Indeed, such persistence of premium for the Indian GDRs has even given rise to a segmentation hypothesis between the Indian GDR and the domestic stock markets (Jithendranathan *et al*, 2000). However, such analogy need not be taken too far and wide. Incidentally, all the Indian ADRs were reportedly issued at a discount to their respective domestic shares. The subsequent emergence of premium on the ADRs, thus, has something to do with the well-known underpricing puzzle associated with the issue of equity. Possibly the Indian ADRs were issued at a discount to make the maiden issues of the foreign companies a success in the US market. Besides, part of the observed premium on the Indian ADR could be a reflection of the potential transaction cost out of brokerage and tax as also the risk premium for Rupee-Dollar exchange rate associated with any conversion of the ADR into the domestic share. More importantly however, the sustenance of premium on ADR could be attributed to the scarcity factor: a product of the inter-play of localised demand-supply in the absence of two-way fungibility of the Indian ADRs. However, the two markets are not isolated from each other. On the contrary, the observed Granger causality running from the Indian ADR price to the underlying domestic share price shows that they are intertwined probably in a common investor base, *viz.*, institutional investors, NRIs, OCBs and PIOs. Towards this end, a number of plausible hypotheses not necessarily mutually exclusive could be put forward.

Table 4: Causality Patterns between Close Quote for ADR and Open Quote at BSE

Company	Granger’s F	Causality Conclusion
1	2	3
1. Infosys	306.582	Nasdaq _{Close} → BSE _{Open}
2. ICICI	81.326	NYSE _{Close} → BSE _{Open}
3. ICICI-Bank	88.006	NYSE _{Close} → BSE _{Open}
4. Silverline	389.941	NYSE _{Close} → BSE _{Open}
5. VSNL	79.5397	NYSE _{Close} → BSE _{Open}
6. WIPRO	314.024	NYSE _{Close} → BSE _{Open}
7. Dr. Reddy’s	79.065	NYSE _{Close} → BSE _{Open}
8. Satyam Computers	241.481	Nasdaq _{Close} → BSE _{Open}
9. HDFC Bank	3.108	NYSE _{Close} → BSE _{Open}
10. MTNL	35.636	NYSE _{Close} → BSE _{Open}

First, quite a few of the dually listed Indian companies have significant international operations. Besides, they are largely export driven powered by the demand from the US economy. No wonder, there exists a strong possibility of the domestic stock being affected by information generated in other foreign markets including the US market. Secondly, the majority of the dually listed Indian companies seem to be working in the area of TMT (*i.e.*, telecommunications, media and information technology and software) or some of its variation and extension. Given the fact that the US market is the global hub of TMT stocks, it is likely that new information on such industry is primarily generated in the US and gets directly

transmitted to the world over or indirectly to the underlying non-US stocks *en route* their ADRs. Finally, the US market has increasingly come to occupy a position of prime mover for the global stock prices. Becker *et al* (1990), among others, have documented that the US market is the primary producer of information that affects other markets in the world. Indeed, Hansda and Ray (2002) have highlighted the leading role of the US market in relation to the Indian market. Even though placed in different time zones, the Indian fund managers seem to be all the more inclined and probably rightly so to take a cue in the short run from the overall or the stock-wise trend in Indian ADR at Nasdaq / NYSE.

The above observation *per se* does not preclude the case for causality from the other direction. Indeed, test of the reverse null hypothesis that the domestic share price at BSE (close) does not cause its corresponding ADR price (open) has provided a new dimension to the perceived relation between the BSE and the Nasdaq/NYSE. The stock-wise close quote at BSE is found to Granger-cause the respective open quote of ADR for each and every of the 10 stocks dually listed at the BSE and the Nasdaq/NYSE (Table 5). Thus, there exists a bi-directional causality between the quotes of Indian ADRs at Nasdaq / NYSE and the quotes at BSE. This is in sharp contrast to the relation obtained at the aggregate level whereby the BSE Sensex was identified to be a satellite to the dominant Nasdaq Composite Index or the IT related indices of the NYSE – the Dow Jones Composite Internet Index or the Dow Jones Index of Internet Commerce (Hansda and Ray, 2002).

Table 5: Causality Patterns between Close Quote at BSE and Open Quote for ADR

Company	Granger's F Statistics	Causality Conclusion
1	2	3
1. Infosys	281.323	BSE _{Close} → Nasdaq _{Open}
2. ICICI	39.752	BSE _{Close} → NYSE _{Open}
3. ICICI-Bank	32.894	BSE _{Close} → NYSE _{Open}
4. Silverline	139.966	BSE _{Close} → NYSE _{Open}
5. VSNL	123.376	BSE _{Close} → NYSE _{Open}
6. WIPRO	223.608	BSE _{Close} → NYSE _{Open}
7. Dr. Reddy's	77.005	BSE _{Close} → NYSE _{Open}
8. Satyam Computers	80.084	BSE _{Close} → Nasdaq _{Open}
9. HDFC Bank	20.350	BSE _{Close} → NYSE _{Open}
10. MTNL	20.996	BSE _{Close} → NYSE _{Open}

Note: As the ADR market at NYSE or Nasdaq opens after the close of the BSE, today's ADR open price has been treated as tomorrow's open price for the purpose of Granger causality. No such adjustment is required for the Granger causality between the close quote for ADR and the open quote at BSE.

The classical finance paradigm also predicts that the asset price remains unaffected by the location of trading albeit under the assumption of perfect integration of capital markets. However, the emergent counterfactual is not without its precedent. There are studies articulating the influence of ownership/trading location on the stock prices of the MNCs (e.g., Froot and Dabora, 1999). Indeed, the discerning relation is not devoid of its intuitive appeal. The group of 10 dually listed companies with their international network symbolises the emergence of indigenous MNCs in their own rights. However, as in the case of MNCs from other countries, they remain largely India-based with the domestic operations exerting an influence on their prospects. Besides, the stocks are reportedly much more actively traded on the BSE vis-à-vis the Nasdaq or NYSE even though the latter provides a vibrant trading location for the Indian ADRs as compared to the London or the Luxemburg Stock Exchange for the Indian GDRs (Kumar and Saudagaran, 2001). The resultant indigenous impulses are predictably transmitted and reflected in the corresponding ADR prices *en route* the domestic stock prices.

The unidirectional causality from the international to domestic stock price index at the macro level, and the bi-directional causality between the quotes of company-specific scrips at the international and domestic market are in expected lines. In fact, the presence of such cross-

currents in the prices of Indian ADRs and underlying domestic stocks has been long recognised, among others, by Shah (1999). Given the over-powering magnitude and dimension of the Nasdaq vis-à-vis the Indian market, such dominant-satellite relation between the two can only be expected at the macro level. While the Nasdaq is the global hub of stocks, the Indian stock market with all its integration with the rest of the world remains largely regional and national in character. Issue of Indian Depository Receipt by foreign companies yet remains a distant dream for the Indian market. The state of the Indian market however does not come in the way of transmission of domestic impulses abroad or their catch-up by the foreign exchanges at the individual stock level.

5.3 What happens if we take National Stock Exchange (NSE) as the domestic market place?

As a test of robustness, the whole exercise has been simultaneously replicated for the competing domestic stock exchange (NSE) facilitated by the fact that all the 10 stocks are also listed on the NSE. Substitution of the NSE open quotes for the BSE ones too has kept the causality outcome unaltered in terms of its stock-wise direction from the Nasdaq or the NYSE to the domestic stock exchange (Table 6). On the other hand, the scenario remains one and the same with the close quote at NSE Granger causing the open quote for ADR at Nasdaq / NYSE (Table 7). Thus, at the individual stock level, NSE shares the same relation with the Nasdaq/NYSE as the BSE. In other words, the Indian and the US stock markets prove to be interdependent at the micro level.

Table 6: Causality Patterns between Close Quote for ADR and Open Quote at NSE

Company	Granger's F Statistics	Causality Conclusion
1	2	3
1. Infosys	354.464	Nasdaq _{Close} → NSE _{Open}
2. ICICI	85.296	NYSE _{Close} → NSE _{Open}
3. ICICI-Bank	100.380	NYSE _{Close} → NSE _{Open}
4. Silverline	335.830	NYSE _{Close} → NSE _{Open}
5. VSNL	92.735	NYSE _{Close} → NSE _{Open}
6. WIPRO	331.084	NYSE _{Close} → NSE _{Open}
7. Dr. Reddy's	71.235	NYSE _{Close} → NSE _{Open}
8. Satyam Computers	203.262	Nasdaq _{Close} → NSE _{Open}
9. HDFC Bank	8.955	NYSE _{Close} → NSE _{Open}
10. MTNL	41.038	NYSE _{Close} → NSE _{Open}

Table 7: Causality Patterns between Close Quote at NSE and Open Quote for ADR

Company	Granger's F Statistics	Causality Conclusion
1	2	3
1. Infosys	283.050	NSE _{Close} → Nasdaq _{Open}
2. ICICI	44.718	NSE _{Close} → NYSE _{Open}
3. ICICI-Bank	41.835	NSE _{Close} → NYSE _{Open}
4. Silverline	181.766	NSE _{Close} → NYSE _{Open}
5. VSNL	141.386	NSE _{Close} → NYSE _{Open}
6. WIPRO	246.425	NSE _{Close} → NYSE _{Open}
7. Dr. Reddy's	74.584	NSE _{Close} → NYSE _{Open}
8. Satyam Computers	85.821	NSE _{Close} → Nasdaq _{Open}
9. HDFC Bank	19.621	NSE _{Close} → NYSE _{Open}
10. MTNL	18.599	NSE _{Close} → NYSE _{Open}

Note: As the ADR market at NYSE or Nasdaq opens after the close of the NSE, today's ADR open price has been treated as tomorrow's open price for the purpose of Granger causality. No such adjustment is required for the Granger causality between the close quote for ADR and the open quote at NSE.

6. Transmission of Impulses between Domestic and Foreign Stock Markets

The presence of stock-wise bi-directional causality does not necessarily ensure efficiency in processing and transmitting information across the markets. In search of such indications, the speed of transmission of the pricing information and its persistence from one market to another has been examined scrip-wise by infusing a price shock in terms of the impulse response function (IRF). Each impulse response represents a moving average coefficient normalised by its standard error. Such normalisation is necessary to compare the impulse responses across variables that have different variations. Symbolically, let $Z_t = A_1 Z_{t-1} + \epsilon_t$ represent a VAR (1) in first difference variables having a vector moving average representation. This can be orthonormalised so that the error terms are not correlated: $Z_t = \sum_{i=0}^{\infty} \Phi_i \epsilon_{t-i}$ where the residuals ϵ_{t-i} are orthogonal. The matrices Φ_i are the IRFs since they represent the behaviour of the modelled series in response to the shocks (innovations). The vector ϵ_t is the vector of innovations: the vector of impacts induced for particular variables when such impacts are independent of each other. Short-run behaviour of prices indicates the stability or instability of the time path, the duration of which is provided by the IRF.

Nevertheless, as Runkle (1987) has shown the IRFs could have wide variations. Furthermore, as the IRFs are related to the VAR coefficients in a non-linear form, the derivation and computation of standard errors in analytical form is difficult. In order to overcome such difficulties, we have adopted the Monte Carlo simulation procedure to compute the standard errors of the IRFs (Hamilton, 1994). At each repetition, a random sample from the asymptotic distribution of the VAR coefficients is drawn. Subsequently, the IRFs are computed from the asymptotic distribution of the VAR coefficients. After repeating this process a number of times, the 95 per cent confidence interval by the percentile method is constructed. The standard errors reported in the Graphs 3 and 4 below are the standard deviations of the simulated impulse responses across 10,000 replications.

Since the US and the Indian trading sessions are not synchronous on a real time basis, under market efficiency information generated in one market should be fully reflected in the opening price of the other market. Towards this end, the stock-wise impulse response of the BSE open quote to a unit standard deviation shock in the corresponding ADR close quote from Nasdaq / NYSE has been carried out and presented for the first day to the seventh day after the shock, with the Monte Carlo standard error bands shown as the dotted lines, in the context of VAR 1, with the Choleski decomposition using the following order: ADR close quote is followed by BSE open quote (Graph 3). Interestingly, magnitude and persistence of the responses of the BSE open quotes to innovations in the Nasdaq/NYSE are quite similar for all the stocks except the one for HDFC Bank. Responses are found to have occurred most strongly on the first day itself after the day of shock and dwindled sharply thereafter in general by the next two days. The first day over-reaction has been followed up by a relatively insignificant under-reaction in the case of six BSE stocks, viz., Silverline Technologies, VSNL, Wipro, Dr Reddy's Laboratories, Satyam Computers and MTNL. Furthermore, the standard errors are seen to be quite close and converging in all the cases, implying the reasonableness of the impulses.

The picture remains broadly the same in respect of the stock-wise impulse response of the ADR open quote in the Nasdaq / NYSE to a unit standard deviation shock in the corresponding BSE close quote in the framework of VAR 2 (Graph 4), with the following order of the variables: BSE close quote is followed by ADR open quote. Even in these cases, standard errors are fairly close. Furthermore, the impulse response of the HDFC Bank's ADR has fallen in line with the behaviour of other ADRs. However, the under-reaction on the second day albeit insignificant remains confined to only three Indian ADRs. In general, both the BSE and the Nasdaq/NYSE are found to be efficient and quick in processing and incorporating

stock-wise information into their respective prices. As a result, there does not seem to have much scope for making profit in one market out of the prior knowledge of price movement in the other closing market. The persistence of impulse responses in the opening market beyond the first day even though relatively insignificant needs to be interpreted keeping in view the possible release of new information after the close of the closing market.

6. Concluding Observations

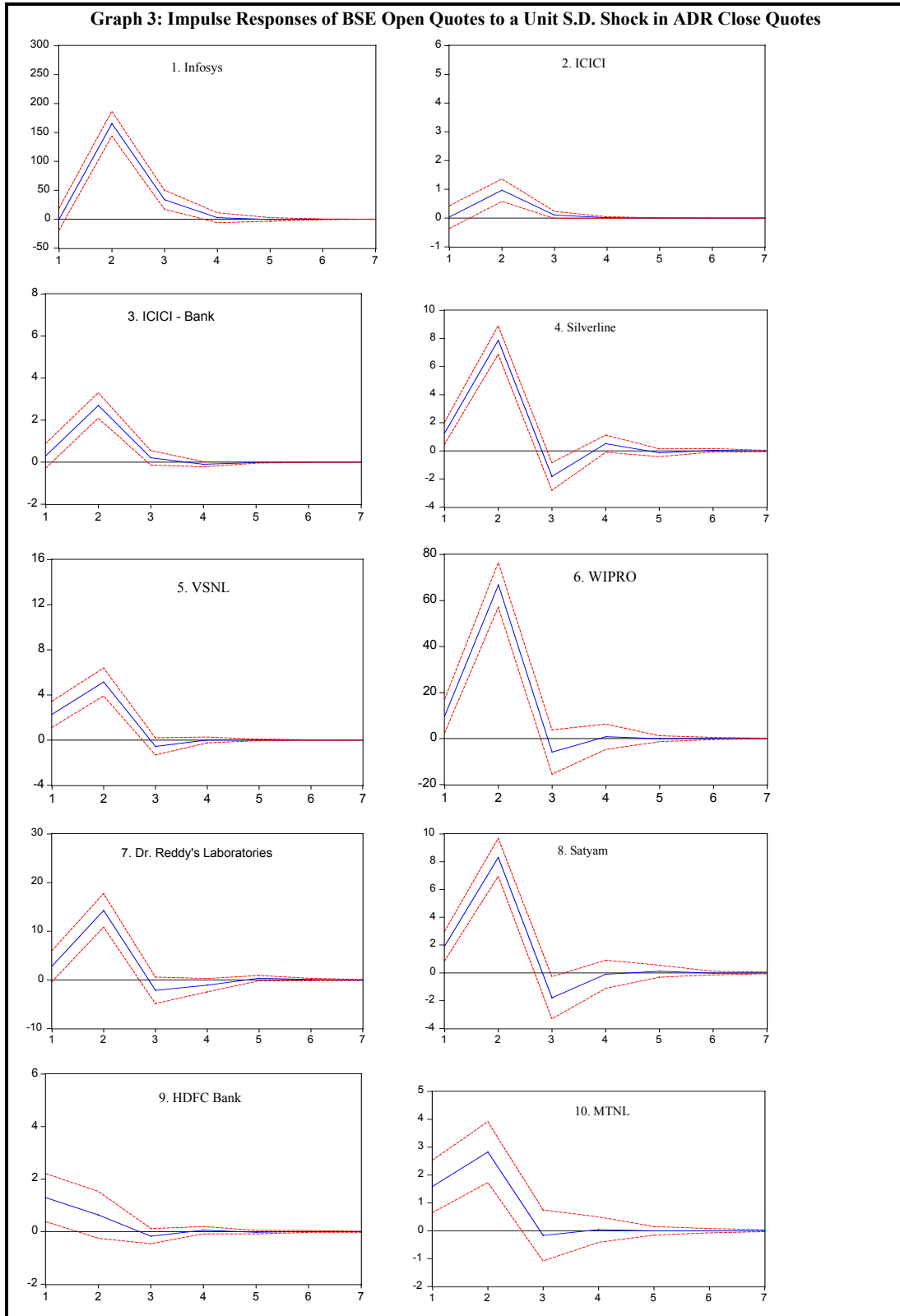
The study built around a multiple quest has been revealing in a number of ways. While the Indian ADR as well as the underlying domestic stock is observed to Granger-cause each other, a standard deviation shock in today's close quote of ADR at Nasdaq / NYSE (close quote at BSE) is found to lead to a hike in tomorrow's open quote at BSE (open quote of ADR at Nasdaq / NYSE). Even though the international and the domestic stock exchanges could share a dominant-satellite relation at the aggregate level, they stand out on an equal footing at the micro level at least for those companies, which have stocks listed in both the exchanges. Even the Indian market has turned out to be an independent source of information and impulses for the corresponding ADR stocks.

The lack of micro-foundation for the macro relation however does not make the latter untenable. On the contrary, the macro emergence of a leader-follower relation across markets appears to be a natural outcome of the limited magnitude and dimension of the Indian stock market vis-à-vis the Nasdaq / NYSE. Perhaps further liberalisation on the domestic front with measures like introduction of Indian Depository Receipt could sow the seeds of a new beginning at the aggregate level.

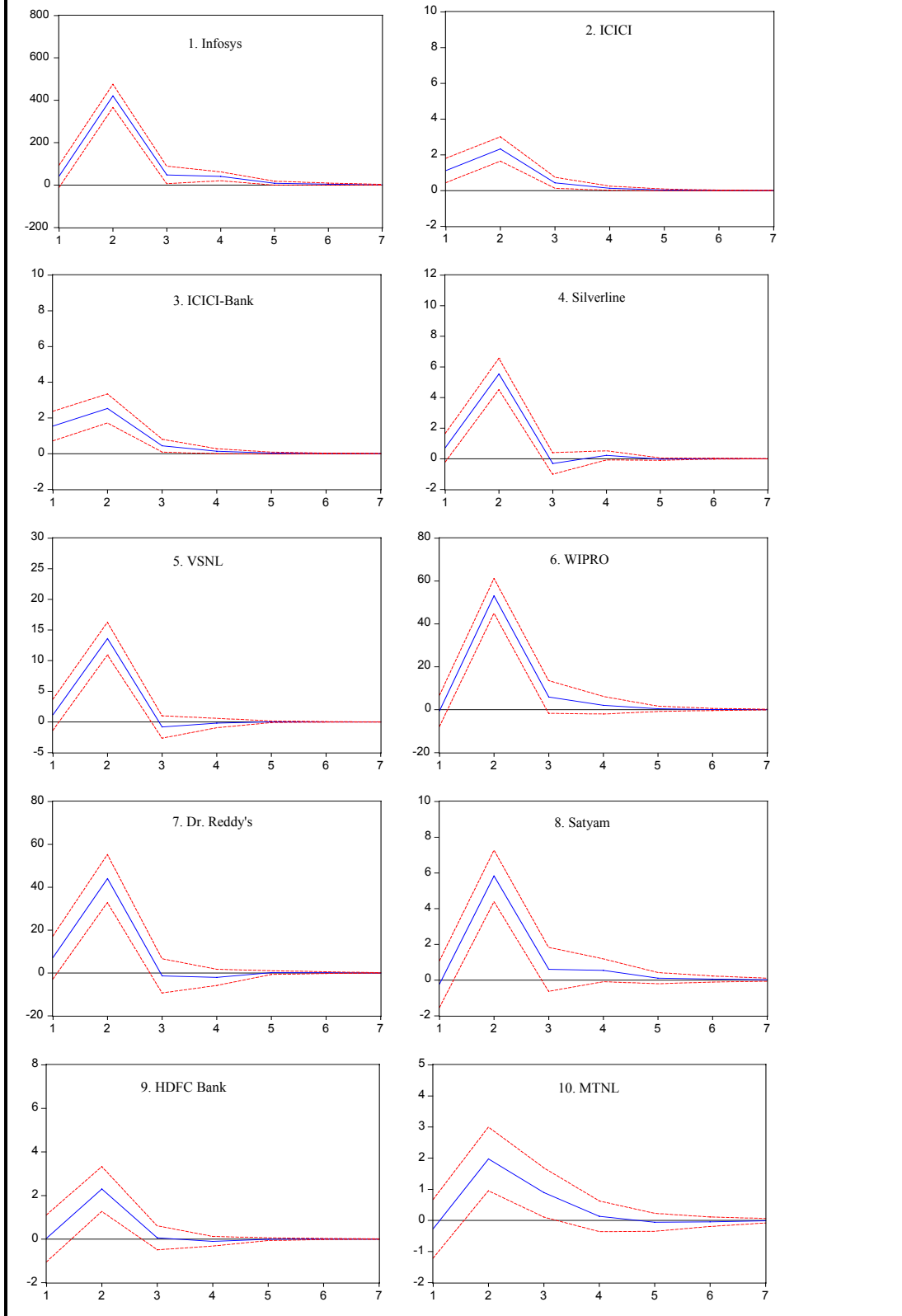
Both the markets are in general found to be vibrant and efficient in quick transmission of the pricing information across the dually listed stocks, limiting the scope for arbitrage-profit out of any prior information on the closing market. Significantly, such catch-up across the markets takes place even without much arbitrage activities in the context of ADR's one-way fungibility and trading at a sustained premium to its domestic counterpart. The inter-twined relation at the micro level between the two markets possibly reflects an underlying common investor base for the ADRs and domestic stocks, *viz.*, Institutional Investors, Non-resident Indians, Overseas Corporate Bodies, and Persons of Indian Origin. The two-way fungibility of ADR from February 2002 albeit facilitating the arbitrage process both ways is expected to have further limited the scope for arbitrage profit in the context of the observed transmission of impulses across the markets.

The impulse responses used in the study, however, do not distinguish between innovations out of stock price and exchange rate. While it may not matter much in the present context of tranquillity in the Indian forex market, the worldwide volatile forex trends hold out a case for analysing the responses of the stock prices to innovations in the forex market as well. This constitutes research agenda for the future.

Graph 3: Impulse Responses of BSE Open Quotes to a Unit S.D. Shock in ADR Close Quotes



Graph 4: Impulse Responses of ADR Open Quotes to a Unit S.D. Shock in BSE Close Quotes



**Appendix Table 1: Correlation Matrix of Prices
at BSE and at Foreign Stock Exchanges**

Company	Variables	BSE-Open	BSE-Close	Foreign-Open	Foreign-Close
1	2	3	4	5	6
1. Infosys	BSE-Open	1.000			
	BSE-Close	0.996	1.000		
	Foreign-Open	0.951	0.951	1.000	
	Foreign-Close	0.948	0.951	0.994	1.000
2. ICICI	BSE-Open	1.000			
	BSE-Close	0.992	1.000		
	Foreign-Open	0.911	0.911	1.000	
	Foreign-Close	0.907	0.910	0.993	1.000
3. ICICI-Bank	BSE-Open	1.000			
	BSE-Close	0.991	1.000		
	Foreign-Open	0.927	0.927	1.000	
	Foreign-Close	0.924	0.926	0.996	1.000
4. Silverline	BSE-Open	1.000			
	BSE-Close	0.997	1.000		
	Foreign-Open	0.992	0.993	1.000	
	Foreign-Close	0.989	0.991	0.998	1.000
5. VSNL	BSE-Open	1.000			
	BSE-Close	0.986	1.000		
	Foreign-Open	0.839	0.849	1.000	
	Foreign-Close	0.834	0.846	0.984	1.000
6. WIPRO	BSE-Open	1.000			
	BSE-Close	0.989	1.000		
	Foreign-Open	0.985	0.988	1.000	
	Foreign-Close	0.978	0.987	0.994	1.000
7. Dr. Reddy's Laboratories	BSE-Open	1.000			
	BSE-Close	0.988	1.000		
	Foreign-Open	0.878	0.890	1.000	
	Foreign-Close	0.867	0.885	0.984	1.000
8. Satyam Computers	BSE-Open	1.000			
	BSE-Close	0.984	1.000		
	Foreign-Open	0.983	0.986	1.000	
	Foreign-Close	0.977	0.990	0.991	1.000
9. HDFC Bank	BSE-Open	1.000			
	BSE-Close	0.884	1.000		
	Foreign-Open	0.690	0.684	1.000	
	Foreign-Close	0.710	0.718	0.920	1.000
10. MTNL	BSE-Open	1.000			
	BSE-Close	0.950	1.000		
	Foreign-Open	0.885	0.881	1.000	
	Foreign-Close	0.867	0.900	0.963	1.000

**Appendix Table 2: Correlation Matrix of Prices
at NSE and at Foreign Stock Exchanges**

Company	Variables	NSE-Open	NSE-Close	Foreign-Open	Foreign-Close
1	2	3	4	5	6
1. Infosys	NSE-Open	1.000			
	NSE-Close	0.996	1.000		
	Foreign-Open	0.952	0.952	1.000	
	Foreign-Close	0.948	0.952	0.994	1.000
2. ICICI	NSE-Open	1.000			
	NSE-Close	0.993	1.000		
	Foreign-Open	0.912	0.914	1.000	
	Foreign-Close	0.908	0.912	0.993	1.000
3. ICICI-Bank	NSE-Open	1.000			
	NSE-Close	0.989	1.000		
	Foreign-Open	0.926	0.928	1.000	
	Foreign-Close	0.924	0.927	0.996	1.000
4. Silverline	NSE-Open	1.000			
	NSE-Close	0.998	1.000		
	Foreign-Open	0.992	0.993	1.000	
	Foreign-Close	0.989	0.991	0.998	1.000
5. VSNL	NSE-Open	1.000			
	NSE-Close	0.984	1.000		
	Foreign-Open	0.839	0.851	1.000	
	Foreign-Close	0.831	0.847	0.984	1.000
6. WIPRO	NSE-Open	1.000			
	NSE-Close	0.990	1.000		
	Foreign-Open	0.985	0.988	1.000	
	Foreign-Close	0.978	0.987	0.994	1.000
7. Dr. Reddy's Laboratories	NSE-Open	1.000			
	NSE-Close	0.987	1.000		
	Foreign-Open	0.878	0.890	1.000	
	Foreign-Close	0.866	0.884	0.984	1.000
8. Satyam Computers	NSE-Open	1.000			
	NSE-Close	0.983	1.000		
	Foreign-Open	0.982	0.986	1.000	
	Foreign-Close	0.976	0.990	0.991	1.000
9. HDFC Bank	NSE-Open	1.000			
	NSE-Close	0.877	1.000		
	Foreign-Open	0.694	0.680	1.000	
	Foreign-Close	0.704	0.713	0.920	1.000
10. MTNL	NSE-Open	1.000			
	NSE-Close	0.941	1.000		
	Foreign-Open	0.874	0.879	1.000	
	Foreign-Close	0.847	0.899	0.963	1.000

**Appendix Table 3: Correlation Matrix of Prices
at BSE and at Foreign Stock Exchanges with 1 Day Lag**

Company	Variables	BSE-Open	BSE-Close	Foreign-Open	Foreign-Close
1	2	3	4	5	6
1. Infosys	BSE-Open	1.000			
	BSE-Close	0.996	1.000		
	Foreign-Open	0.954	0.949	1.000	
	Foreign-Close	0.955	0.953	0.994	1.000
2. ICICI	BSE-Open	1.000			
	BSE-Close	0.992	1.000		
	Foreign-Open	0.911	0.908	1.000	
	Foreign-Close	0.912	0.910	0.993	1.000
3. ICICI-Bank	BSE-Open	1.000			
	BSE-Close	0.991	1.000		
	Foreign-Open	0.928	0.926	1.000	
	Foreign-Close	0.928	0.926	0.996	1.000
4. Silverline	BSE-Open	1.000			
	BSE-Close	0.997	1.000		
	Foreign-Open	0.993	0.992	1.000	
	Foreign-Close	0.992	0.991	0.998	1.000
5. VSNL	BSE-Open	1.000			
	BSE-Close	0.986	1.000		
	Foreign-Open	0.850	0.837	1.000	
	Foreign-Close	0.849	0.842	0.984	1.000
6. WIPRO	BSE-Open	1.000			
	BSE-Close	0.990	1.000		
	Foreign-Open	0.986	0.979	1.000	
	Foreign-Close	0.987	0.982	0.994	1.000
7. Dr. Reddy's Laboratories	BSE-Open	1.000			
	BSE-Close	0.988	1.000		
	Foreign-Open	0.880	0.878	1.000	
	Foreign-Close	0.879	0.883	0.984	1.000
8. Satyam Computers	BSE-Open	1.000			
	BSE-Close	0.984	1.000		
	Foreign-Open	0.981	0.970	1.000	
	Foreign-Close	0.988	0.975	0.991	1.000
9. HDFC Bank	BSE-Open	1.000			
	BSE-Close	0.884	1.000		
	Foreign-Open	0.597	0.559	1.000	
	Foreign-Close	0.650	0.639	0.918	1.000
10. MTNL	BSE-Open	1.000			
	BSE-Close	0.951	1.000		
	Foreign-Open	0.857	0.805	1.000	
	Foreign-Close	0.883	0.835	0.963	1.000

**Appendix Table 4: Correlation Matrix of Prices
at NSE and at Foreign Stock Exchanges with 1 Day Lag**

Company	Variables	NSE-Open	NSE-Close	Foreign-Open	Foreign-Close
1	2	3	4	5	6
1. Infosys	NSE-Open	1.000			
	NSE-Close	0.996	1.000		
	Foreign-Open	0.954	0.951	1.000	
	Foreign-Close	0.956	0.954	0.994	1.000
2. ICICI	NSE-Open	1.000			
	NSE-Close	0.993	1.000		
	Foreign-Open	0.911	0.912	1.000	
	Foreign-Close	0.913	0.913	0.993	1.000
3. ICICI-Bank	NSE-Open	1.000			
	NSE-Close	0.989	1.000		
	Foreign-Open	0.926	0.926	1.000	
	Foreign-Close	0.928	0.926	0.996	1.000
4. Silverline	NSE-Open	1.000			
	NSE-Close	0.998	1.000		
	Foreign-Open	0.992	0.992	1.000	
	Foreign-Close	0.992	0.991	0.998	1.000
5. VSNL	NSE-Open	1.000			
	NSE-Close	0.984	1.000		
	Foreign-Open	0.849	0.840	1.000	
	Foreign-Close	0.849	0.845	0.984	1.000
6. WIPRO	NSE-Open	1.000			
	NSE-Close	0.990	1.000		
	Foreign-Open	0.985	0.979	1.000	
	Foreign-Close	0.987	0.982	0.994	1.000
7. Dr. Reddy's Laboratories	NSE-Open	1.000			
	NSE-Close	0.987	1.000		
	Foreign-Open	0.879	0.879	1.000	
	Foreign-Close	0.879	0.883	0.984	1.000
8. Satyam Computers	NSE-Open	1.000			
	NSE-Close	0.983	1.000		
	Foreign-Open	0.980	0.971	1.000	
	Foreign-Close	0.987	0.976	0.991	1.000
9. HDFC Bank	NSE-Open	1.000			
	NSE-Close	0.877	1.000		
	Foreign-Open	0.613	0.559	1.000	
	Foreign-Close	0.669	0.640	0.918	1.000
10. MTNL	NSE-Open	1.000			
	NSE-Close	0.941	1.000		
	Foreign-Open	0.849	0.805	1.000	
	Foreign-Close	0.869	0.834	0.963	1.000

**Appendix Table 5: Time Series Properties of Stock Prices Quotes –
Dickey Fuller Test Statistics**

Company	BSE - Open	BSE- Close	NSE – Open	NSE- Close	Foreign- Open	Foreign- Close
1	3	4	5	6	7	8
I. Level^a						
1) Infosys	-2.061	-1.933	-1.997	-1.957	-2.118	-2.195
2) ICICI	-3.637	-3.481	-1.630	-1.548	-3.630	-3.626
3) ICICI-Bank	-3.059	-2.965	-2.416	-2.073	-2.284	-2.247
4) Silverline	-1.598	-1.476	-2.162	-2.080	-1.900	-1.510
5) VSNL	-2.339	-2.175	-1.716	-1.521	-2.387	-2.490
6) WIPRO	-1.751	-1.743	-1.552	-1.586	-1.520	-1.556
7) Dr. Reddy's	-2.913	-2.744	-1.745	-1.887	-2.431	-2.522
8) Satyam	-2.025	-2.275	-0.820	-1.117	-2.096	-2.169
9) HDFC Bank	-3.350	-3.527	-3.060	-3.193	-3.113	-2.940
10) MTNL	-1.387	-2.067	-0.918	-2.022	-1.727	-1.963
II. First Differences^b						
1) Infosys	-17.810	-15.903	-17.447	-16.382	-21.766	-20.943
2) ICICI	-16.502	-14.539	-16.712	-14.522	-17.159	-16.951
3) ICICI-Bank	-16.253	-16.182	-17.642	-16.255	-16.221	-16.521
4) Silverline	-15.699	-15.593	-17.653	-15.324	-13.056	-13.267
5) VSNL	-15.854	-14.612	-15.881	-14.339	-14.395	-14.077
6) WIPRO	-13.180	-12.331	-13.485	-12.636	-13.045	-13.637
7) Dr. Reddy's	-12.889	-12.071	-13.161	-11.911	-11.059	-11.120
8) Satyam	-10.465	-9.413	-11.675	-9.539	-8.972	-10.331
9) HDFC Bank	-9.902	-10.927	-10.648	-10.582	-7.709	-9.289
10) MTNL	-6.855	-6.716	-5.839	-6.844	-5.269	-5.750

a Equation includes an intercept and time trend.

b Equation includes an intercept term.

Note: The 95 per cent critical values for a and b are -3.718 and -2.865 , respectively.

Endnotes

¹ The *BSE Annual Capital Market Review 2000-01* has explicitly recognised this development: “...(T)he correlation, in particular, has been more pronounced in the case of heavily technology-weighted indices. While emerging market daily correlations with the Nasdaq were in the range of 20-50 per cent over the period 1992-2000, during the last two years: 1999-2000, these correlations have been in the range of around 60-80 per cent. The major contributors to this trend were the Asian indices because Asia as a region became increasingly dependent on technology exports to developed countries...” (p 44).

² Depository receipts (DRs) are essentially equity instruments, issued outside the country to non-resident investors, by authorized Overseas Depository Banks (ODBs) against the shares/bonds of domestic companies, held with the nominated domestic custodian banks. DRs issued in the US and in the rest of the world are known as the ADRs and GDRs respectively. FCCBs are meant for subscription by non-residents in foreign currency and are convertible into ordinary shares of the issuing company.

³ Our sample consists of the following ten companies: 1. Infosys (March 1999 to February 2002); 2. ICICI (October 1999 to February 2002); 3. ICICI Bank (March 2000 to February 2002); 4. Silverline (June 2000 to February 2002); 5. VSNL (August 2000 to February 2002); 6. WIPRO (October 2000 to February 2002); 7. Dr. Reddy’s Laboratories (April 2001 to February 2002); 8. Satyam Computers (May 2001 to February 2002); 9. HDFC Bank (July 2001 to February 2002); and 10. MTNL (October 2001 to February 2002). The primary data used in this paper are culled from two basic sources, viz., (1) respective company web-sites, and (2) Moneyline Telerate.

⁴ For the sake of comparison, the prices of the ADRs have been converted to domestic currency and in terms of domestic share. That is to say, if P^F and P^D be the prices in Nasdaq / NYSE and BSE, respectively, θ be the ratio of a domestic stock to ADR, and e be the exchange rate of Rupee per unit of US Dollar, then, in rest of the paper, we will be working on P^D and θeP^F . Thus, ADR quotes in rest of the paper will actually point to θeP^F , as the price of the ADR (in comparable unit) in domestic currency. This was done to capture the pure arbitrage opportunity from across the capital markets between the two countries.

⁵ Computation of the coefficient of correlation on the basis of the first difference of the variables brings out a higher magnitude between the open price on the domestic stock exchange and the close price on the foreign stock exchange on the previous day or between the close price on the domestic stock exchange and the open price on the foreign stock exchange on the same day.

⁶ Since the variables under consideration are found to be $I(1)$, it may be argued that one has to check for any possible existence of cointegrating relationship(s) among the variables, and in the case of a cointegrating relationship a VAR in first differences could be a misspecification, *a la* Granger Representation Theorem; in such a case, one needs to have the VAR in vector error-correction model (Engle and Granger, 1987). Nevertheless, considering the short-term nature of our analysis, we have neglected the issue of cointegration of these variables, and hence did not include any error correction term in the VARs.

References

- Agarwal, R. N., 2000, 'Financial Integration and Capital Markets in Developing Countries: A Study of Growth, Volatility and Efficiency in the Indian Capital Market', *mimeo*, Institute of Economic Growth, Delhi.
- Alexander, G. J., Eun, C. S., and Janakiraman, S., 1988, 'International Listings and Stock Returns: Some Empirical Evidence', *Journal of Financial and Quantitative Analysis*, 23 (2), 839-855.
- Amihud, Y. and Mendelson, H., 1995, 'Multimarket Trading: A Self-Regulatory Proposal', in Schwartz, R. A. and Walter, L. (eds.), *Global Equity Markets: Technological, Competitive, and Regulatory Challenges*, Irwin, New York, 342-351.
- Bae, K., Cha, B., and Cheung, Y., 1999, 'The Transmission of Pricing Information of Dually-Listed Stocks', *Journal of Business Finance & Accounting*, 26 (5) & (6), June/July, 709-23.
- Becker, K., Finnerty, J., and Gupta, M., 1990, 'The Intertemporal Relation Between the US and Japanese Stock Markets', *Journal of Finance*, 45, 1297-1306.
- Bennett, P. and Keller, J., 1988, 'The International Transmission of Stock Price Disruption in October 1987', *Federal Reserve Bank of New York Quarterly Review*, Summer, 17-33.
- Brooks, R. and Catao, L., 2000, 'The New Economy and Global Stock Returns', Working Paper 216, International Monetary Fund, December.
- Chowdhry, B. and Nanda, V., 1991, 'Multimarket Trading and Market Liquidity', *Review of Financial Studies*, 4, 483-511.
- Domowitz, I., Glen, J. D., and Madhavan, A., 1997, 'Market Segmentation and Stock Prices: Evidence from an Emerging Market', *Journal of Finance*, 52 (3), 1059-1085.
- Domowitz, I., Glen, J. D., and Madhavan, A., 1998, 'International Cross-listing and Order Flow Migration: Evidence from an Emerging Market', *Journal of Finance*, 53, 2001-27.
- Engle, R., and Granger, C.W.J., 1987, 'Co-Integration and Error Correction: Representation, Estimation and Testing', *Econometrica*, 55, 251-276.
- Foerster, S. R. and Karolyi, G. N., 1999, 'The Effects of Market Segmentation and Investor Recognition on Asset Prices: Evidence from Foreign Stocks Listing in the United States', *The Journal of Finance*, 54 (3), 981-1013.
- Froot, K. and Dabora, E., 1999, 'How are Stock Prices Affected by the Location of Trade?', *Journal of Financial Economics*, 53, 189-216.
- Garbade, K. D. and Silber, W. L., 1979, 'Dominant and Satellite Markets: A Study of Dually Traded Securities', *Review of Economics and Statistics*, 61, 455-460.
- Granger, C. W. J., 1969, 'Investigating Causal Relations by Econometric Models and Cross-Spectral Models', *Econometrica*, 37, 424-38.
- Grubel, H., 1968, 'Internationally Diversified Portfolio: Welfare Gains and Capital Flows', *American Economic Review*, 58(5), 1299-1314.
- Hamilton, J., 1979, 'Marketplace Fragmentation, Competition, and the Efficiency of the Stock Exchange', *Journal of Finance*, 34, 171-187.
- Hamilton, J. D., 1994, *Time Series Analysis*, Princeton: Princeton University Press.
- Hansda, Sanjay K. and Ray, Partha, 2002, 'BSE and Nasdaq: Globalisation, Information Technology and Stock Prices', *Economic and Political Weekly*, 37 (5), February 2, 459-468.
- Heston, S. L. and Rouwenhorst, K. G., 1994, 'Does Industrial Structure Explain the Benefits of International Diversification', *Journal of Financial Economics*, 36, 3-27.
- Hobijin, B. and Jovanovic, B., 2000, 'The Information Technology Revolution and the Stock Market: Evidence', NBER Working Paper No. 7684, May.
- Howe, J. S. and Madura, J., 1990, 'The Impact of International Listings on Risk: The Implications for Capital Market Integration', *Journal of Banking and Finance*, 14, 1133-1142.

- Ignatius, R., 1992, 'The Bombay Stock Exchange: Seasonalities and Investment Opportunities', *Indian Economic Review*, 27, 223-27.
- Jayaraman, N., Shastri, K., and Tandon, K., 1993, 'The Impact of International Cross Listings on Risk and Return', *Journal of Banking and Finance*, 17 (1), 91-103.
- Jithendranathan, T., Nirmalanandan, T. R., and Tandon, K., 2000, 'Barriers to International Investing and Market Segmentation: Evidence from Indian GDR Market', *Pacific-Basin Finance Journal*, 8, 399-417.
- Kumar, M. and Saudagaran, S. M., 2001, 'The Impact of International Listings on Liquidity: Evidence from the Indian Stock Market', Fifth Capital Markets Conference 2001, December 20-21, UTI Institute of Capital Markets, Navi Mumbai.
- Lau, S. T. and Diltz, J. D., 1994, 'Stock Returns and the Transfer of Information Between the New York and Tokyo Stock Exchanges', *Journal of International Money and Finance*, 13 (2), 211-22.
- Lessard, D., 1973, 'International Portfolio Diversification: A Multivariate Analysis for a Group of Latin American Countries', *Journal of Finance*, 28 (3), 619-633.
- Lieberman, O., Ben-Zion, U., and Hauser, S., 1999, 'A Characterization of the Price Behavior of International Dual Stocks: An Error Correction Approach', *Journal of International Money and Finance*, 18, 289-304.
- Mittoo, U., 1992, 'Managerial Perceptions of the Net Benefits of Foreign Listing: Canadian Experience', *Journal of International Financial Management and Accounting*, 4, 40-62.
- Neumark, D., Tinsley, P. A., and Tosini, S. S., 1991, 'After Hours Stock Prices and Post Crash Hangovers', *Journal of Finance*, 46, 159-178.
- Noronha, G., Sarin, A., and Saudagaran, S. M., 1996, 'Testing for Microstructure Effects of International Dual Listings using Intraday Data', *Journal of Banking and Finance*, 20, 965-983.
- Patil, R. H., 1994, 'Capital Market Developments', *The Journal of the Indian Institute of Bankers*, 65 (3), July-September, 106-110, 139.
- Rosenthal, L., 1983, 'An Empirical Test of the Efficiency of the ADR Market', *Journal of Banking and Finance*, 7, 17-30.
- Runkle, D. E., 1987, 'Vector Autoregressions and Reality', *Journal of Business and Economic Statistics*, 5, 437-42.
- Shah, A., 1995, 'The Tale of One Market Inefficiency: Abnormal Returns around GDR Issues by Indian Firms', Centre for Monitoring Indian Economy, available at <http://www.cmie.ernet.in/~ajayshah/PROSE/ARTICLES/gdr.ps.gz>.
- Shah, A., 1999, 'Vulnerability on the Stock Market', *Business Standard* column, available at <http://www.igidr.ac.in/~ajayshah/MEDIA/crashes.html>
