PRICING OF INFRASTRUCTURE EQUITIES: A TEST OF EFFICIENCY IN AN EMERGING MARKET

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ABSTRACT

The Indian economy has experienced rapid growth following a liberalization of economic and financial policies in the 1990s. Sustaining such growth requires significant investments in infrastructure, which renders the sector potentially attractive to market participants and brings into focus the question of capital market efficiency. The present study tests the stocks of infrastructure companies in this growing economy for weak form efficiency. Fractal analysis of the returns on 25 individual stocks comprising Indian infrastructure indices reveals the existence of significant long-range dependence within the majority of the series. Specifically, results are consistent with the notion that market participants overreact to new information, inducing volatility in excess of what might be expected for a random walk. Evidence of pricing inefficiencies would be of interest not only to technical traders seeking profit opportunities but also to policy makers concerned about attracting much needed capital into the infrastructure industry.

Key Words: Market efficiency, Fractal analysis, Rescaled Range Analysis, India, Infrastructure stocks.

JEL Codes: G10, G12, G14

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I. INTRODUCTION

Following its far-reaching economic reforms in 1991, India has emerged as a significant player in the world economy. However, the country's continuing integration into the global economy is critically dependent on a satisfactory development of infrastructure, including transportation, logistics, communication, information infrastructure capital markets, and energy (Sheth, 2004). Much progress has been made in this regard, but numerous challenges remain, and significant amounts of investment are still needed. For example, in an interview in 2005, Prime Minister Manmohan Singh, the architect of the liberalization policy of the 1990s, estimated that the country would require roughly $150 billion of investment over the coming seven to eight years on account of the "large backlog" in infrastructure (Gupta, 2005). The shift in emphasis from public to private enterprise following India's economic liberalization heightens the importance of properly functioning financial markets in the mobilization of such investment. Even though measures of reform have encompassed a large cross-section of the economy, including banking, international trade, and the markets for capital and labor (Guha-Khasnobis & Bhaduri, 2000), the financial sector does face challenges. For example, shareholdings and control are highly concentrated, markets for debt are underdeveloped, analyst forecasts and services are relatively meager, and substantial information asymmetry plagues the capital markets (Bhattacharya et al, 2003; Reddy & Rath, 2005).

In the context of an economy in this phase of transition, it is relevant to ask how efficiently the markets value assets. As Dicle et al (2010) suggest, such a question would be of concern to policy makers seeking to attract investment into critical sectors. Infrastructure, as noted above, is one such sector. A cursory look at the recent price behavior of some of the leading infrastructure stocks indicates a pattern resembling a bubble. Each of the figures below (Figures 1 through 4) depicts the price behavior of three representative stocks within one of four major infrastructure sectors, viz. Power, Electrical Equipment, Construction, and Telecommunications. For purposes of comparison, the stock prices have been rescaled to the base value as of June 1, 2006 (with the exception of Construction, for which the benchmark prices are those on August 21, 2006 due to non-availability of data prior to this date for one of the comparison stocks).

Figure 1
Stock Price Behavior, June 2006-March 2009: Power Sector

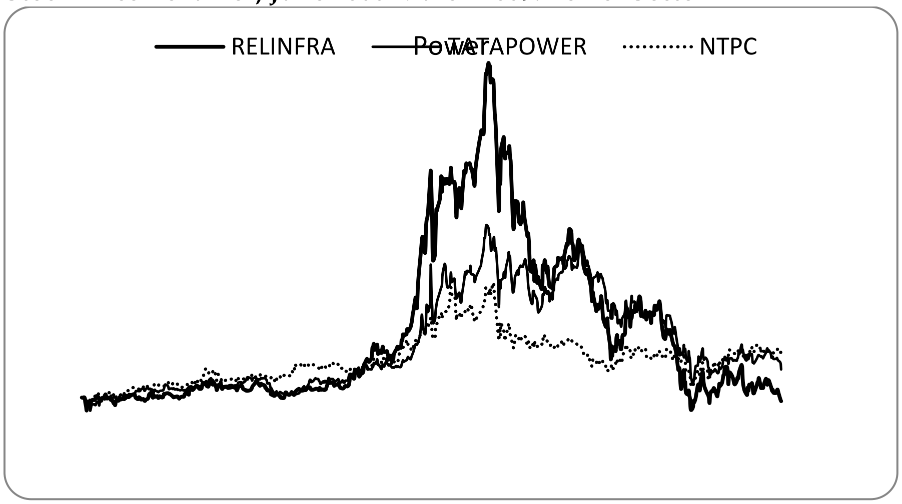


Figure 2
Stock Price Behavior, June 2006-March 2009: Electrical Equipment Sector

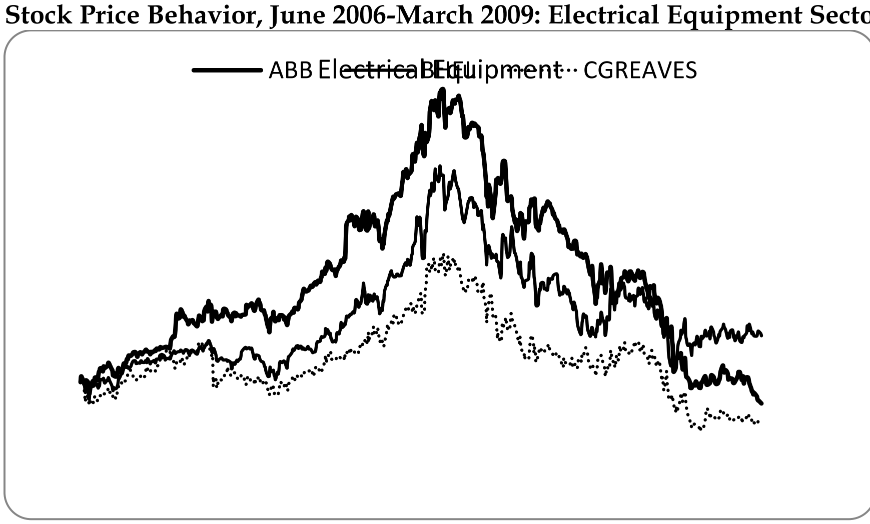


Figure 3
Stock Price Behavior, August 2006-March 2009: Construction Sector

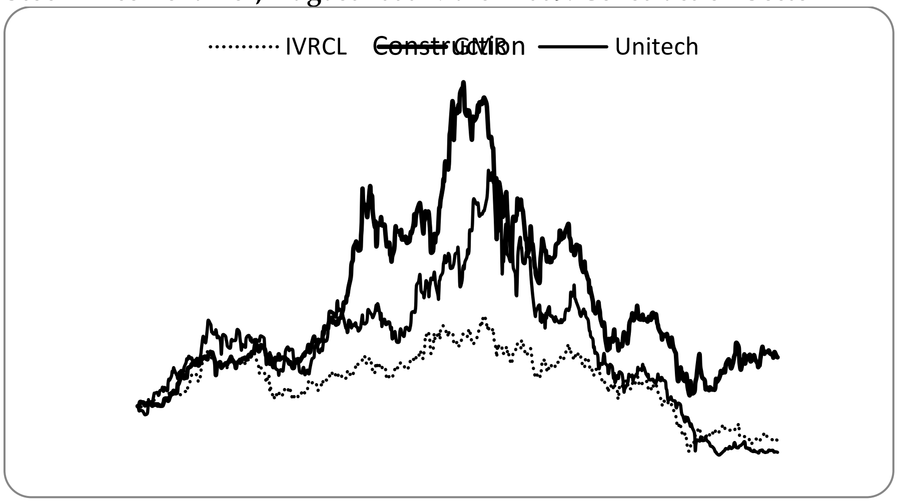
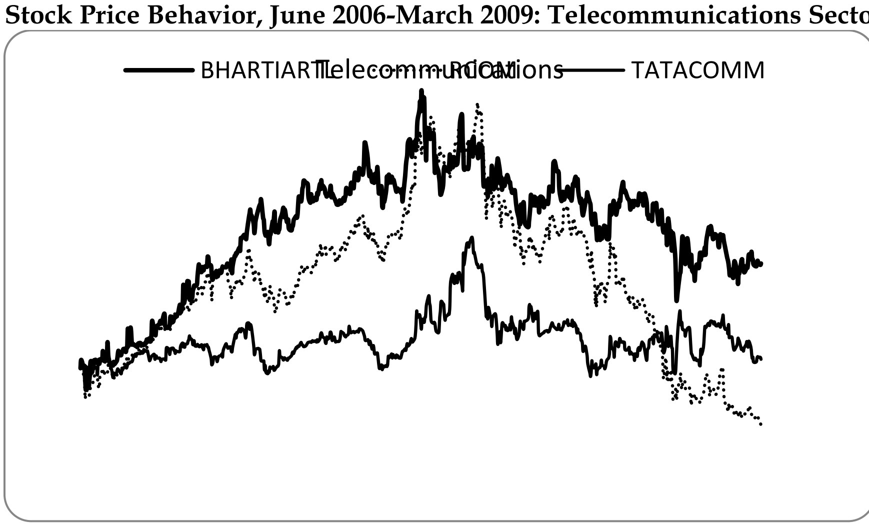


Figure 4
Stock Price Behavior, June 2006-March 2009: Telecommunications Sector



Overall, we can observe a sharp increase in prices starting in 2007, followed by a steep decline beginning in 2008. This pattern is common to the sectors, even though the magnitude of change varies across, and even within, each sector. For instance, among the power sector firms depicted, Reliance Infrastructure (RELINFRA) peak prices were in excess of 500% of base value, as against 250% of base value for NTPC. Across these major sectors, the magnitude of change was the lowest for telecommunications, with a peak price of slightly over 300% of base value for Bharti Airtel (BHARTIARTL); the change was largest for construction, with peak price (for GMR) in excess of 600% of base value.

The present study covers the period of June 2006 through March 2009—a period of apparently significant divergence of value from a norm—to formally test for the presence of informational inefficiencies in the pricing of Indian infrastructure equities. It employs classical rescaled range (R/S) analysis to estimate the fractal dimension of the returns series for each of the 25 infrastructure companies that comprise the CNX Infrastructure index, and thus to test for the existence of persistence (or antipersistence) in returns. The study seeks to contribute to the growing literature on informational efficiency in developing markets, and has practical implications for policy makers seeking to attract foreign investment into this critical sector, for market participants considering portfolio allocation into infrastructure, and for investors employing technical trading rules.

The remainder of the paper is organized as follows. The section below provides a brief account of the changes in the Indian infrastructure sector (including relevant regulatory policy initiatives), and on the still nascent study of market efficiency in this emerging economy. This is followed by a description of the data and methodology employed in the study. The results are then presented and discussed. The last section summarizes the study's findings, implications, and limitations. It also provides suggestions for further research.

II. LITERATURE REVIEW & BACKGROUND

A. Market Efficiency

Recent research indicates a growing interest in the question of market efficiency in the Indian context. The question of market efficiency is not only of academic interest, but has practical implications as well—for domestic investors seeking abnormal returns, for international investors contemplating diversification into the Indian market, and for Indian policy makers hoping to attract the flow of foreign investment. Poshakwale (2002) represents a relatively early study of this question. Investigating the behavior of stock returns on the Bombay Stock Exchange (BSE), he finds no support for the random walk hypothesis. His results point to non-linear dependence and persistence in volatility for daily returns on a portfolio of stocks as well as on stocks of individual firms. The study of returns on several stock indices by Sarkar and Mukhopadhyay (2005) reveals some market predictability, consistent with a lack of efficiency in the weak form. These results stand in contrast to Chander et al (2008), whose findings indicate independence in returns. Similarly, in their study of the performance of mutual funds, Sehgal & Jhanwar (2008) find little evidence of returns persistence. Dicle et al (2010), who investigate the potential benefit of diversification into the Indian market, suggest the possibility of returns predictability in that market based on the presence of a strong causality from world markets. Further, results of runs tests on individual stocks are consistent with non-random behavior.

In a recent study of semi-strong efficiency based on event study methodology, Raja & Sudhahar (2010) find that the announcement of bonus issues by Indian information technology (IT) firms is partially anticipated by the market within a few days of the event, that there is significant market reaction on the event day, and that there is some impounding of information for several days following announcement. With the standard caveats attached to modeling, these leads and lags may be interpreted to mean that the market is not perfectly efficient at least in the semi-strong form.

The foregoing review of studies indicates that the evidence on market efficiency is mixed, though the weight of that evidence appears to be in favor of informational inefficiency. Given the context of India's growth in the post-liberalization period, and the importance of infrastructure development to a sustaining of that growth, examining the rationality of infrastructure equity pricing is of some interest. This is so particularly in view of the trend of reduced government control of infrastructure development, and the concomitant increase in the presence of private capital in that sector. For instance, a large flow of private financing driven by an unbridled optimism regarding returns to infrastructure investments in a rapidly growing emerging market could lead to speculative pricing, and even bubbles. It is to a brief discussion of these changes in the infrastructure sector that we now turn.

B. Liberalization of Government Policy

Policy makers and researchers have identified infrastructure as a significant constraint on Indian economic growth. For instance, speaking in 2005, Prime Minister Manmohan Singh himself estimated the need for roughly $150 billion in infrastructure investment for the latter part of the decade (Gupta, 2005). Sheth (2004) identifies infrastructure as the "weakest link" in India's effort to integrate into the global economy, with inadequate infrastructure acting as a significant drag on productivity. He points to the need for growth in private equity investments to provide an impetus to development in this sector. A McKinsey survey of senior managers of multinational corporations ranks India (jointly with Russia) last in terms of infrastructure among the 16 countries covered by the study (Fairell et al, 2005).

Still, the trend of changes has been positive. The liberalization programs initiated in 1991 have increased foreign direct investment (FDI) into infrastructure, and policy makers recognize the urgent need to boost such investment further; as of 2005, for instance, the government set itself the goal of roughly tripling the amount of FDI flowing into the sector within three years, and tripling it yet again within two more years after that (Zainulbhai, 2005). One indication of this commitment was the permission in March 2005 for a 100% FDI into the construction sector, subject to certain conditions (see, for example, Thacker, 2005). Indeed, the traditionally strict controls on foreign investment being removed, 100% FDI is now allowed in most sectors of the infrastructure industry. Further, the tax code was amended in 2005 to allow tax exemptions for profits earned by entities from infrastructure support to the special economic zones (SECs) in India, though several concessions were reversed the following year (Purandare et al, 2005; Patel, 2006).

The effect of government policy initiatives with regard to FDI are reflected in the changes in FDI into Indian infrastructure. Table 1 presents the total annual FDI inflows into infrastructure from fiscal year 2003-04 through the first half of fiscal year 2007-08. It also provides the annual FDI inflows into the three major recipients of this inflow, viz. Construction, Power, and Telecommunications.

Table 1
FDI into Indian infrastructure, Fiscal Years 2003/04-2007/08

Fiscal Year	Infrastucture	Construction	Power	Telecom
2003-04	388.37	n/a	n/a	116
2004-05	456.00	152	n/a	129
2005-06	914.04	151	87	624
2006-07	2179.39	985	157	478
2007-08*	4095.80	1743	967	1261
2008-09	n/a	2028	985	2558

*Total FDI figure is for partial fiscal year, i.e., as of December 2007.
Source: Government of India, Ministry of Commerce & Industry

The FDI figures show a substantial spurt in foreign investment into the infrastructure industry, with all the three major sub-sectors for which data are available experiencing large increases in the inflow of capital, especially following fiscal year 2004-05. This study seeks to test formally for weak form efficiency of the infrastructure equity markets, focusing on a period spanning June 2006 through March 2009. The methodology and data employed in the study are discussed next.

III. DATA AND METHODOLOGY

The daily closing prices for each of the 25 firms comprising the CNX Infrastructure Index are collected from the national stock exchange (NSE) website [nseindia.com]. These are adjusted for stock splits. Not all the infrastructure firms have price data going back to June 2006; for these, the analysis is performed with the first available data. Table 2 provides a summary of the firm-wise information employed by the study. Note that, owing to data constraints, the dates and/or sample size differ for the following six companies—DLF, GMR, Unitech, Siemens, Reliance Power, and Idea Cellular.

This study employs Mandelbrot's (1972) rescaled-range (R/S) analysis to estimate the self-affinity index (Hurst exponent, H) of the returns series. Classical R/S analysis stems from the work of Hurst's (1951) seminal study of the Nile river[2]. To describe R/S analysis, let us define a time series x with n consecutive values $x = x_1, x_2, \ldots, x_n$. The mean and standard deviation, x_m, and s_n are:

$$x_m = \frac{\sum_{i=1}^{n} x_i}{n} \text{; and}$$

$$s_n = \sqrt{\frac{\sum_{i=1}^{n} (x_i - x_m)^2}{n}}$$

The range is the difference between the maximum and minimum cumulative deviation values over the n observations:

$$R = \mathrm{Max}\left[\sum_{i=1}^{n} (x_i - x_m)\right] - \mathrm{Min}\left[\sum_{i=1}^{n} (x_i - x_m)\right]$$

This range must be nonnegative, given the fact that x has been redefined to a mean of zero; the maximum must be at least zero, the minimum can be at most zero. The range can be viewed as the distance traveled by the system in time n, and since for systems following Brownian motion, the distance covered is proportional to the square root of time, T (the "T to the one-half rule"), we have: $R = T^{0.50}$

A generalized form of this rule for time series characterized by dependence rather than Brownian motion is (Hurst, 1951):

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[2] For recent use of R/S analysis to study equity returns behavior, see Mulligan (2004), *inter alia*.

$R/s_n = k \times n^H$

The left-hand-side is the range scaled by the standard deviation of the series ("rescaled range"), k is a constant, and H is the "Hurst exponent". The relationship describes how the range of the cumulated deviations from mean scales over the time increment, n; for a random time series, H would be 0.50. Taking the logarithm of the above expression, we have:

$\log R/s_n = \log k + H \log n$

The Hurst exponent can thus be estimated as the slope of the plot of log R/s_n against log n. In practice, H is estimated by dividing the series into contiguous subperiods and using OLS to estimate H[3]. For example, if a data series (logarithmic returns) has 680 observations, the series is divided successively into contiguous periods of length n, where n will assume values of whole integer factors of 680 (i.e. 2, 4, 5, 8, 10, 17, 20, etc). For each of these n, therefore, a corresponding average range and standard deviation can be calculated (for instance, there will 340 windows of length 2, and 170 windows of length 4, etc). The logarithm of the average R/S value thus obtained for the window length, n, is regressed on the logarithm of the window length. The coefficient of log n then provides the estimate of the Hurst exponent, or scaling exponent, H. The fractal dimension of the series is D = 2-H. For a random series, or independent process, H = 0.50. If $0.50 < H \leq 1$, then the series is "persistent"— elements in the series influence other elements in the series. If $0 \leq H < 0.50$, then the series is "anti-persistent", and the process reverses itself more frequently than a random process would.

Table 2
Summary information for firms in the sample

Company Name	Industry	NSE Symbol	Dates	N
DLF Ltd.	CONSTRUCTION	DLF	07/5/07-04/15/10	685
GMR Infrastructure Ltd.	CONSTRUCTION	GMRINFRA	08/23/06-06/02/09	685
IVRCL Infrastructures & Projects Ltd.	CONSTRUCTION	IVRCLINFRA	06/01/06-03/03/09	685
Punj Lloyd Ltd.	CONSTRUCTION	PUNJLLOYD	06/01/06-03/03/09	685
Unitech Ltd.	CONSTRUCTION	UNITECH	06/23/06-03/03/09	675
Jaiprakash Associates Ltd.	DIVERSIFIED	JPASSOCIAT	06/01/06-03/03/09	685
ABB Ltd.	ELECTRICAL EQUIP	ABB	06/01/06-	685

[3]Peters (1994), pp. 61-63, provides a step-by-step guide to estimating H.

			03/03/09	
Bharat Heavy Electricals Ltd.	ELECTRICAL EQUIP	BHEL	06/01/06-03/03/09	685
Crompton Greaves Ltd.	ELECTRICAL EQUIP	CROMPGREAV	06/01/06-03/03/09	685
Siemens Ltd.	ELECTRICAL EQUIP	SIEMENS	06/13/06-03/03/09	677
Suzlon Energy Ltd.	ELECTRICAL EQUIP	SUZLON	06/01/06-03/03/09	685
Larsen & Toubro Ltd.	ENGINEERING	LT	06/01/06-03/03/09	685
Indian Hotels Co. Ltd.	HOTELS	INDHOTEL	06/01/06-03/03/09	685
NTPC Ltd.	POWER	NTPC	06/01/06-03/03/09	685
Neyveli Lignite Corporation Ltd.	POWER	NEYVELILIG	06/01/06-03/03/09	685
Reliance Infrastructure Ltd.	POWER	RELINFRA	06/01/06-03/03/09	685
Reliance Power Ltd.	POWER	RPOWER	02/11/08-09/09/10	634
Tata Power Co. Ltd.	POWER	TATAPOWER	06/01/06-03/03/09	685
Shipping Corporation of India Ltd.	SHIPPING	SCI	06/01/06-03/03/09	685
Bharti Airtel Ltd.	TELECOM	BHARTIARTL	06/01/06-03/03/09	685
Idea Cellular Ltd.	TELECOM	IDEA	03/09/07-12/04/09	676
Mahanagar Telephone Nigam Ltd.	TELECOM	MTNL	06/01/06-03/03/09	685
Reliance Communications Ltd.	TELECOM	RCOM	06/01/06-03/03/09	685
Tata Communications Ltd.	TELECOM	TATACOMM	06/01/06-03/03/09	685
Jet Airways (India) Ltd.	TRANSPORT	JETAIRWAYS	06/01/06-03/03/09	685

Following Peters (1992), the price data for the 25 firms listed in Table 2 are converted into logarithmic returns prior to the estimation of the Hurst exponent. The results of the R/S analysis for the infrastructure stock returns series are presented and discussed in the next section.

IV. EMPIRICAL RESULTS

The results of the R/S analysis for the 25 returns series are presented in Table 3 below. $\hat{H}$ indicates that the estimated Hurst exponent. The null hypothesis for the tests is H = 0.500. Significance of estimated coefficients is indicated by asterisks. The sector to which each firm belongs is included so as to facilitate inter-sector comparison of results.

The estimates of H indicate a little variability in returns behavior across as well as within sectors. Specifically, we see that results are not consistently significant for the Construction and Telecommunications sectors. Also, the returns of the two firms representing the Diversified and Transportation sectors (Jaiprakash Associates Ltd. and Jet Airways, respectively) do not show departure from random behavior. However, there are a couple of strong patterns that can be observed. First, the null is rejected for 18 of the 25 infrastructure firms, indicating that the returns of the majority of the firms in the industry exhibited behavior inconsistent with a random process. Second, the vast majority of returns series appear to be antipersistent, with estimated characteristic exponents less than 0.500; Punj Loyd and Reliance Power, which exhibit persistent, or trend-reinforcing behavior, are the two exceptions.

Another notable feature of the results is that all the Electrical Equipment sector stocks exhibit strong antipersistence. Finally, Crompton Greaves (Electrical Equipment sector) and Bharti Airtel (Telecom sector) stand out as two firms with particularly strong negative dependence in returns, with estimated exponents of 0.390 and 0.296, respectively.

Table 3
Estimated Hurst exponents for Indian infrastructure stock returns

	Company Name	Sector	$\hat{H}$	Std. Err
1	DLF Ltd.	CONSTRUCTION	0.489	.0186
2	GMR Infrastructure Ltd.	CONSTRUCTION	0.506	.0132
3	IVRCL Infrastructures & Projects Ltd.	CONSTRUCTION	0.451***	.0067
4	Punj Lloyd Ltd.	CONSTRUCTION	0.523***	.0068
5	Unitech Ltd.	CONSTRUCTION	0.482	.0201
6	Jaiprakash Associates Ltd.	DIVERSIFIED	0.497	.0044
7	ABB Ltd.	ELECTRICAL EQUIP	0.456***	.0140
8	Bharat Heavy Electricals Ltd.	ELECTRICAL EQUIP	0.430***	.0127
9	Crompton Greaves Ltd.	ELECTRICAL EQUIP	0.390***	.0043
10	Siemens Ltd.	ELECTRICAL EQUIP	0.453***	.0067
11	Suzlon Energy Ltd.	ELECTRICAL EQUIP	0.439***	.0127
12	Larsen & Toubro Ltd.	ENGINEERING	0.420***	.0137
13	Indian Hotels Co. Ltd.	HOTELS	0.440***	.0085
14	NTPC Ltd.	POWER	0.412***	.0148

15	Neyveli Lignite Corporation Ltd.	POWER	0.455**	.0156
16	Reliance Infrastructure Ltd.	POWER	0.467**	.0115
17	Reliance Power Ltd.	POWER	0.525**	.0098
18	Tata Power Co. Ltd.	POWER	0.416***	.0235
19	Shipping Corporation of India Ltd.	SHIPPING	0.432**	.0308
20	Bharti Airtel Ltd.	TELECOM	0.296***	.0340
21	Idea Cellular Ltd.	TELECOM	0.475	.0235
22	Mahanagar Telephone Nigam Ltd.	TELECOM	0.471	.0256
23	Reliance Communications Ltd.	TELECOM	0.429***	.0068
24	Tata Communications Ltd.	TELECOM	0.445**	.0194
25	Jet Airways (India) Ltd.	TRANSPORT	0.483	.0384

*significant at α = 10%
**significant at α = 5%
***significant at α = 1%

V. CONCLUSIONS AND IMPLICATIONS

The results of this study provide strong evidence of inefficiencies in the pricing of infrastructure equities. Specifically, it is observed that several of the returns series exhibit antipersistent behavior, indicating that they reverse themselves more frequently than a random process would. Such a pattern is at least consistent with mean-reverting processes (assuming a stable mean), and with the notion that the market tends to overreact to the arrival of new information. It is unclear as to why two of the firms indicate a different pattern of persistence, in which past trend is reinforced rather than reversed.

Overall, though, these results have important implications for investors and policy makers. The presence of dependence in returns indicates that technical trading rules might in fact provide systematic excess returns, provided the precise nature of the dependence is identified and incorporated into the trading rules. For policy makers seeking to attract domestic and international investment into such a critical development-related sector, a lack of informational efficiency would be of some concern, to the extent that such a sector attracts speculative investments rather than financing commitments anchored on fundamentals and long-term growth prospects. Furthermore, the observed antipersistence in returns (which indicates that volatility is greater than that for a random walk), may stem from the poor quality of firm-specific information available to market participants. As Chakrabarti et al (2008) have noted, for instance, India's accounting standards depart in many ways from the International Accounting Standards (IAS), giving firms considerable leeway in financial reporting, and making interpretation of financial statements somewhat difficult. Regulators may need to act quickly to encourage greater transparency and consistency in corporate reporting. For funds seeking avenues for portfolio allocation, India's urgent need for substantial infrastructure improvements, combined with the government's apparent commitment to easing controls on private and foreign investment, makes this sector an attractive long-term investment opportunity, provided capital markets function fairly efficiently.

This study contributes to the literature on market efficiency in emerging markets, and points to a recent episode of significant divergence from rational pricing in a critical sector of a major developing economy. Certain limitations of the study should however be noted. First, its results pertain to a specific period (June 2006 through March 2009) during which the infrastructure sector saw a large run up and subsequent decline in equity values. Thus, these results apply to a period resembling a classic bubble. With time, the availability of additional data will allow a more general and comprehensive test, with the added advantage of greater stability in estimates. Also, even though the spurt in prices roughly coincided with the increased flow of FDI, testing for a causal relationship is beyond the scope of this paper. Second, it should be noted that conventional hypothesis testing around the null of H = 0.500 makes implicit assumptions about the underlying distribution and its asymptotic normality. Studies—such as those by Couillard & Davison (2005) and Jin & Frechette (2004)—indicate that finite samples generated from random walk processes will yield $\hat{H}$ in excess of 0.500. For example, Monte Carlo simulations by Jin & Frechette (2004) yielded $E[\hat{H}]$ mainly in the region of 0.530. Using a null of H = 0.500 may introduce a bias towards rejecting that null in favor of H>0.500 (or persistence in the returns series). This shortcoming of conventional testing does not, however, detract from the conclusions of the present study, since 16 of the 18 significant characteristic exponents fall in the antipersistent range (<0.500).

A related criticism of the classical R/S analysis is that its sensitivity to short-term dependence may introduce a bias in the estimated Hurst exponent (Lo, 1991). Therefore, it is recommended that the behavior of Indian infrastructure equity returns documented here be supplemented with evidence based on a model akin to Lo's modified rescaled range analysis, which distinguishes between long-range dependence and short-memory processes. Such an analysis is left to a future study.

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