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Speed of information adjustment in Indian stock indices

P. Krishna Prasanna [a,*], Anish S. Menon [b,1]

[a] *Department of Management Studies, Indian Institute of Technology, Madras, Chennai 600036, Tamil Nadu, India*
[b] *Indian Institute of Management, Bangalore, Room No. P 214 (Hostel Block), Bannerghatta Road, Bangalore, Karnataka 560076, India*

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Abstract This study attempts to analyse the speed at which information gets incorporated into the various stock indices in India. Four alternate speed estimators viz., the AR (1) model, the ARMA (1, 1) model, the ARMA (1, *X*) model, and the cross-covariance estimator were calculated to estimate the rate at which information is adjusted. The lead—lag relationships between indices with varied characteristics were also analysed. It was observed that the Sensex and the Nifty indices, the constituents of which are large capitalisation stocks, led the smaller indices till 2009. This was disturbed in 2010 and 2011, especially by bank indices.

Introduction

The integration of the Indian stock market with the world markets has caused the absorption of both domestic as well as global news into the market prices and indices. The stock markets in India, viz., the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE) have developed a number of indices to gauge and understand market performance. The present study estimates the speed of information adjustment coefficients of various stock indices in India during the years 2005—2011, in order to examine the improvements in market efficiency during this period as a result of the market initiatives and integration. The speed at which the stock prices and indices adjust to new information provides lead—lag relationships in the markets and facilitates our understanding of the price discovery process. Understanding these patterns helps investors to make their investment choices and decisions.

Much of the research in this field is dedicated to finding a measure to estimate the speed of information adjustment in the stock market. The research broadly measures either the price adjustments of individual stocks and constructed portfolios or the speed with which the market indices absorb the news. The present study measures the speed of adjustments for Indian stock market indices. The visibility of the impact of reforms on the stock markets and their contribution to the efficiency of the markets can be gauged by the information assimilation by indices.

* Corresponding author. Tel.: +91 44 22574571.
E-mail addresses: pkp@iitm.ac.in, pkp_prasanna@yahoo.co.in (P.K. Prasanna), anish.menon@iimb.ernet.in (A.S. Menon).
[1] Tel.: +91 8971949951.
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In India, the studies in this area have not been as prolific as in the West. According to Marisetty (2003), and Poshakwale and Theobald (2004), the Indian markets demonstrated a general trend of under-reaction indicating a slower pace of information absorption. Acharya (2010) observed that as far as the speed of information adjustment is concerned, there is no "size effect" in the Indian stock markets. Both large and small stocks absorb the news at the same speed.

This study attempts to analyse the speed at which information gets incorporated into the various stock indices in India. Four alternate speed estimators, i.e., the Autoregressive (AR (1)) model, the Autoregressive Moving Average (ARMA (1, 1)) model, the Autoregressive Moving Average (ARMA (1, X)) model and the cross-covariance estimator were calculated to estimate the rate at which information is adjusted. Further, the lead—lag relationships between indices with varied characteristics have also been analysed.

This research study contributes to the existing literature on the speed of information adjustment in the Indian market, termed an emerging market in the global landscape. It also analyses the impact of the financial crisis on Indian market behaviour and on the efficiency with which information is assimilated. Such a study is of importance to both policy makers and investors. The research will help in assessing the effects of policy decisions that led to reforms, especially in the area of corporate governance, and on the working of the stock markets. Patterns in the stock price behaviour are of great importance to investors as understanding the patterns would help them in their asset allocation strategies.

The 2008 financial crisis and its aftermath affected markets across the globe. The equilibrium of the Indian markets in turn was disturbed, creating scenarios that had not been experienced before. In the context of the price discovery process, confused signals usually cause erratic behaviour in stock prices. The speed and efficiency with which the markets assimilate this information into the prices is an interesting and comparatively new territory of study in the Indian context. The fore mentioned factors motivated this study to investigate the stock market price discovery process in an index series.

The speed at which the benchmark indices, the Sensex and the Nifty, adjust to the information increased during the study period indicating an improvement in the efficiency of the Indian stock market. It was observed that these indices, the constituents of which are large capitalisation stocks, led the smaller indices. Nifty in NSE and Sensex in BSE led other indices till the year 2009. The speed of information adjustment was also higher in the Nifty and Sensex index series. The speed also improved consistently from 2005 to 2009 and was sustained during the period of financial crisis. This pattern however was disturbed in 2010 and 2011, especially in the banking indices. The Bankex, exclusively composed of banking stocks, was the most affected index during the financial crisis. The speed of information adjustment reduced substantially for this index during this time period.

The rest of the paper is as follows: The second section deals with the literature review; the third section explains the data and methodology; the fourth section presents the analysis and inference, and the fifth section presents the conclusion.

Information adjustment across indices

Indices play a unique role in information assimilation. Index constituents are the most highly traded and the most liquid stocks in case of a general index. Sectoral indices include the top performing stocks in the sector. Indices are more closely tracked than individual stocks, thereby making them more sensitive to any information that affects the economy.

There is a substantial volume of literature on how to measure the speed of information adjustment in stock prices. The studies on the speed of information fundamentally focus on two aspects: the theory defining the speed of adjustment of information; and the methodology behind measuring it. The research studies have measured the speed using regression models, correlation and autocorrelations, vector autoregression (VAR) models, autoregressive conditional heteroskedasticity (ARCH) related models, noise based, and other models.

Marisetty (2003) used the model proposed by Damodaran (1993), and corrected by Brisley and Theobald (1996) to study Indian stock indices. He observed that the Indian markets were prone to an initial phase of overreaction before the observed stock prices reflected their intrinsic values. He noted that the Indian markets were sluggish in adjusting to information as compared to their more developed Western counterparts. He attributed this to the artificial instability caused by the investors who not only had access to private information, but also preferred a fluctuating market to a stable one. He also noticed that the information available to all the market participants got adjusted much faster since the information was available to all market participants as compared to firm specific information. Using the alternative autocovariance method he reported that the BSE-Sensex is more efficient in adjusting to market information than the Nifty, which he said displays overreaction.

In their study of the indices in the BSE and the NSE, Poshakwale and Theobald (2004) analysed the cross correlation patterns to determine the lead—lag relationship between indices with large market capitalisation and those with small market capitalisation. They calculated the speed of information adjustment using five different estimators and also studied the effects of thin trading in the adjustment of information by trying to isolate the effects of pure thin trading. They found that indices with small market capitalisation were slower in adjusting to information than the indices with large market capitalisation, and also that pure thin trading effects had a considerable influence on the lead—lag patterns.

The generalised conditional autoregressive heteroskedasticity (GARCH) model was used by Sivakumar (2010) to examine the information adjustment in the BSE during intraday trading hours. He observed that new information received was given precedence for an interval of 5 min and was completely assimilated in 30 min. For estimating the speed of information adjustment of companies, he used market capitalisation as the index, and found no difference in the speed of adjustment between small and large companies.

An auto-regressive moving average (ARMA) model was employed by Acharya (2010) to study the quality or structure of the market using the speed of information adjustment coefficients. He found that firm size had no impact in the adjustment of information speed.

The ARMA estimator proposed by Theobald and Yallup (2004) to estimate the speed of information adjustment coefficient was used by Joshi (2011) to study the speed of information adjustments in daily, weekly, and monthly intervals. He observed that the speed of information adjustment in the prices during 2002—2007 had increased, unlike 1995—2001, where he had discerned the presence of both over- and under-reactions. In the period 2002—2007, he could only observe significant over-reactions. The degree of reaction was more pronounced in the daily intervals as compared to the weekly or monthly time spans.

Data and methodology

Sample indices and characteristics

The study sample consisted of 12 indices, 6 each from the BSE and the NSE respectively. The study period extended from 2005 to 2011.

The Bombay Stock Exchange is a world leader in terms of the number of listed companies with over 9200 listed companies as on March, 2012. It is the world's fifth most active stock exchange with regard to the number of transactions handled. The BSE has launched various indices including sectoral indices. The following six indices from the BSE were chosen for the study: the BSE Sensex, the BSE500 index, the BSE Bankex, the Dollex200 index, the BSE Midcap index, and the BSE Smallcap index.

The National Stock Exchange formed in 1992 is one of the major stock exchanges in the world and the largest in India in terms of the number of trades in equity. Like the BSE, the NSE too has several indices that include sectoral indices as well. The six indices used in this study are the S&P CNX Nifty index, the CNX Nifty Junior index, the S&P CNX 500 index, the CNX Midcap index, the CNX MNC index, and the CNX Bank index. A brief explanation of each index is given in Table 1.

Data sources

The data was collected from the BSE website (www.bseindia.com), the NSE website (www.nseindia.com) and from the CMIE (Centre for Monitoring Indian Economy) Prowess database. The daily closing values of the indices were collected for the seven year period of 2005—2011. These were collected on the basis of the calendar year. Log returns of the indices were calculated by first differencing using the formula:

$$R_{it} = \ln P_{it} - \ln P_{it-1} \tag{1}$$

where, R_{it} is the return of the index i at time t and P_{it} is the closing value of the index i at time t, and ln refers to the natural log of returns. Stationarity of the data has been tested using the Phillip Perron (PP) Test and the Augmented Dickey Fuller (ADF) Test.

Speed of information adjustment: alternate estimators

The study aims to estimate the speed of information adjustment in the selected indices using four different estimators, including

1. The cross-covariance ratio estimator
2. An ARMA (1, 1) model
3. An ARMA (1, X) model
4. An AR (1) model

The cross-covariance estimator

The cross-covariance estimator was introduced by Theobald and Yallup (1998) to measure the speed of adjustment of the price of securities towards their intrinsic values and to directly measure the degree of under-reaction or over-reaction of the stock prices. The speed of adjustment estimator, $g(i)$, was given by

Table 1 Sample indices of BSE and NSE: characteristics.

Market	Name of index	Launch year	Base period	Base value	Number of constituents	Description
BSE	BSE SENSEX	1986	1978—79	100	30	Broad based
	BSE500	09/08/1999	01/02/1999	1000	500	Broad based
	BSE BANKEX	23/06/2003	01/01/2002	1000	14[a]	Sectoral-banking
	BSE DOLLEX	27/05/1994	1989—90	100	200	Broad based
	BSE Midcap	11/04/2005	2002—03	1000	250[a]	Broad based
	BSE Smallcap	11/04/2005	2002—03	1000	533[a]	Broad based
NSE	S&P CNX Nifty	04/1996	03/11/1995	1000	50	Broad based
	CNX Nifty Junior	01/01/1997	01/11/1996	1000	50	Broad based
	S&P 500	07-Jun-1999	01/01/1994	1000	500	Broad based
	CNX Midcap index	18 July 2005	01/01/2003	1000	100[a]	Broad based
	CNX MNC index	01/01/1995	0112/1994	1000	15	Broad based
	CNX Bank index	01/01/2000	01/01/2000	1000	12	Sectoral-banking

[a] As on the 23rd of May, 2012.

$$(1-g(i))=\frac{cov\{R(i,t),R(i^c,t-1)\}}{cov\{R(i,t),R(i^c,t)\}} \quad (2)$$

Where *cov* is the covariance operator, $R(i,\ t)$ is the return on the stock, index, or any other instrument, i, in period t and the superscript c denotes the complement i.e., any other stock, index, or instrument.

Poshakwale and Theobald (2004) used this estimator to determine the speed of adjustment of the indices. The estimator is a ratio of the autocovariance of two time series. The speed of adjustment $g(i)$, where $i = O, R$ is given by

$$g(O)=1-\left\{cov[R(L,t-1),R(S,t)]\{cov[R(L,t),R(S,t)]\}^{-1}\right\} \quad (3)$$

and

$$g(R)=1-\left\{cov[R(L,t),R(S,t-1)]\{cov[R(L,t),R(S,t)]\}^{-1}\right\} \quad (4)$$

where $g(O)$ and $g(R)$ are the speed of adjustment estimators for the observed and referenced index respectively, *cov* is the covariance between the fore mentioned time series, $R(O)$ and $R(R)$ are returns of the referenced index and observed index at time t respectively and $R(R,\ t-1)$ and $R(O,\ t-1)$ are returns of the observed index and referenced index at 1 lag.

The ARMA (1, 1) model

Theobald and Yallup (2004) introduced an ARMA (1, 1) model to measure the speed of adjustment. The ARMA model can be expressed as

$$R(i,t)=g(i)\mu+(1-g(i))R(t-1)+g(i)e(i,t)+u(t)-u(t-1) \quad (5)$$

where, $R(i,\ t)$ is the return of instrument i at time t and $R(i,\ t-1)$ is the return of instrument i at time $t-1$ (the returns are represented in logarithmic terms), $g(i)$ is the speed of adjustment coefficient of instrument i, $u(t)$ and $u(t-1)$ are the white noise terms at time t and $t-1$ respectively, μ is the mean of the intrinsic values which follows a random walk process and $e(i,\ t)$ are the innovations in the random walk process which in efficient markets will not be serially correlated. The speed of adjustment coefficient $g(i)$ is assumed to be stationary and will have a range of [0, 2] in case of non-explosive processes; $g(i)$ will be equal to 1 if the prices are adjusted fully without any bias, less than 1 in case of under-reaction, and greater than 1 in case of over-reaction.

In this process, the ARMA (1, 1) reflects the autocorrelations that result from over-reactions or under-reactions. The speed of adjustment is captured by the AR (1) process and the speed of adjustment coefficient will be the AR (1) coefficient. When the adjustment is "full" (i.e., $g(i) = 1$), the process is a MA (1) process. This means that the return process is driven by "noise".

The ARMA (1, *X*) model

The ARMA (1, *X*) model is a modification of the ARMA (1, 1) model. Proposed by Theobald and Yallup (2004), the optimal moving average order *X*, is determined by using the Schwarz Information Criterion (SIC). The SIC was proposed by Schwarz (1978) to identify the model with the best fit. The SIC is defined as

$$\mathrm{SIC}=n^{k/n}\frac{\sum\hat{u}^2}{n} \quad (6)$$

or in the log normal form

$$\ln \mathrm{SIC}=\frac{k}{n}\ln\ n+\ln\frac{\sum\hat{u}^2}{n} \quad (7)$$

where, $\sum\hat{u}^2$ is the residual sum of squares (RSS) which is the square of the unexplained variation of the dependant variable about the regression line. The lower the RSS, the tighter the model fit. Here, k is the number of regressors including the intercept and n is the number of observations, and $[(k/n)\ \ln n]$ is the penalty factor. The lower the value of SIC, the better the model.

The AR (1) model

The AR (1) model is a modified version of the ARMA (1, 1) model, wherein the MA component is omitted on the assumptions that there is no disturbance due to noise or spread. The premise of this model is that if the cause of the lead—lag relationship due to the nature of market capitalisation is only due to the faster adjustment of information in large cap indices as compared to small cap indices, then the speed of adjustment of large cap indices should be higher than that of the small cap indices. In case the effect of thin trading exists on this relationship of lead—lag, then taking this effect into account should reduce the difference in the adjustment speeds, thus leading to fuller adjustment of information, i.e., the estimator should approach 1.

Empirical results

Descriptive statistics

Most Indian companies list their shares on both the BSE and the NSE and their shares get traded on both markets. The difference in the traded volume and value results in a marginal difference in the stock returns across these two markets. The descriptive statistics of the index daily returns are given in Table 2A for NSE indices and Table 2B for BSE indices. Between the two competing indices, the Sensex of BSE and the Nifty of NSE, the Sensex provided slightly higher returns. The discrete annual returns in a year (with 250 working days) was 12.07% (i.e., 250*0.000483) on the Sensex and 11.25% (i.e., 250*0.00045) on the Nifty.

Among the NSE indices, the CNX MNC index performed well in terms of highest returns with lowest volatility (standard deviation). This index tracks the presence of multinational companies (MNCs) in the NSE. It comprises shares in which the foreign shareholding is over 50% and/or the management control is vested in the foreign company. As on December 31, 2011, it represented about 4.64% of the total market capitalisation of the NSE and 80.74% of the market capitalisation of the MNCs in the market. It also represented 6.74% of the total traded value on the NSE in the past six months as on December 31, 2011.

CNX Bankex provided the next highest returns but with the highest risk (standard deviation was highest in this index). This index consists of 12 of the most liquid banking stocks in the NSE.

Table 2A Descriptive statistics of NSE indices.

		CNX Bank	Midcap	MNC	Nifty junior	Nifty	S&P500
Overall	Mean	0.000468	0.000401	0.000545	0.000354	0.000450	0.000388
	Std. dev.	0.022396	0.016479	0.014601	0.019280	0.017651	0.016965
	Skewness	0.074948	−0.703714	−0.475110	−0.448642	−0.007056	−0.227437
	Kurtosis	6.984956	9.321640	8.363660	8.545105	10.478810	10.23289
	Jarque—Bera	1150.932	3035.696	2147.494	2283.671	4048.132	3801.252
	Probability	0	0	0	0	0	0
2005—07	Mean	0.001371	0.001476	0.001201	0.001360	0.001423	0.001430
	Std. dev.	0.018745	0.014667	0.013469	0.016681	0.014726	0.014185
	Skewness	−0.227652	−1.105756	−0.678456	−0.879966	−0.460784	−0.748412
	Kurtosis	4.426443	8.101956	6.602892	7.606804	5.428924	6.345100
	Jarque—Bera	69.97037	964.9849	462.5712	758.9867	210.6238	419.1335
	Probability	0	0	0	0	0	0
2008—11	Mean	−0.000216	−0.000414	0.000048	−0.000409	−0.000287	−0.000402
	Std. dev.	0.024796	0.017693	0.015393	0.021014	0.019555	0.018770
	Skewness	0.207183	−0.479701	−0.346314	−0.235758	0.188942	0.003469
	Kurtosis	7.110467	9.446948	8.985159	8.382066	10.96142	10.48645
	Jarque—Bera	702.6176	1748.908	1494.426	1201.612	2615.194	2307.269
	Probability	0	0	0	0	0	0

The Nifty index provided the next higher returns with moderate risk profile. Further, the returns on an average increased during the years 2005—2007 across all the NSE indices. The financial crisis resulted in negative returns and highest risks in the year 2008 across all indices. Though 2009 reflected a recovery phase initially, it could not sustain the trend. The global risk factors such as the crisis in the European Union resulted in volatile markets. BSE indices also demonstrated a similar trend. Among the BSE indices, Bankex gave the highest return and also entailed higher risk; Sensex provided the next highest return with moderate risk.

All series, except the bank indices, in both the BSE and NSE, had higher kurtosis that reflected flatter distribution as compared to normal distribution. The indices in both the BSE and NSE were negatively skewed except for the bank indices which were positively skewed in most of the years. All the indices were found to be significantly non-normal as per the Jarque—Bera statistics.

Cross autocorrelations across indices

Cross autocorrelations of the NSE and BSE indices are presented in Tables 3A and 3B respectively. First order

Table 2B Descriptive statistics of BSE indices.

		Bankex	BSE500	Dollex200	Midcap	Sensex	Smallcap
Overall	Mean	0.000513	0.000412	0.000299	0.000295	0.000483	0.000264
	Std. dev.	0.022342	0.017010	0.019454	0.016601	0.017684	0.017218
	Skewness	0.080263	−0.233866	−0.153376	−0.824453	0.104471	−0.866600
	Kurtosis	7.500400	9.648433	8.086271	9.231715	9.608881	7.062383
	Jarque—Bera	1467.719	3214.929	1879.162	3007.411	3164.305	1411.815
	Probability	0	0	0	0	0	0
2005—07	Mean	0.0014850	0.0014847	0.0015793	0.0015444	0.0014833	0.001785
	Std. dev.	0.0179539	0.0140872	0.0152714	0.0141705	0.0143559	0.015870
	Skewness	-0.2254425	-0.7114187	-0.5055742	−1.342084	-0.3753097	−1.281430
	Kurtosis	4.400328	6.396744	6.326491	8.462359	5.549587	7.099255
	Jarque—Bera	67.54124	423.2572	377.2421	1156.035	220.4504	729.4059
	Probability	0	0	0	0	0	0
2008—11	Mean	−0.000224	−0.000402	−0.000672	−0.000653	−0.000275	−0.000888
	Std. dev.	0.025148	0.018894	0.022063	0.018179	0.019812	0.018097
	Skewness	0.204295	−0.019438	0.010784	−0.561608	0.293435	−0.614281
	Kurtosis	7.381158	9.684034	7.514567	8.916221	9.625260	7.017711
	Jarque—Bera	797.0480	1839.237	839.0498	1492.839	1821.151	726.6479
	Probability	0	0	0	0	0	0

Table 3A NSE cross-correlations.

Overall	CNXMNC$_t$	Nifty$_t$		CNXMidcap$_t$	Nifty$_t$		CNXNiftyJunior$_t$	Nifty$_t$		CNXBank$_t$	Nifty$_t$		CNXS&P500$_t$	Nifty$_t$
CNXMNC$_{t-1}$	0.0860	0.0273	CNXMidcap$_{t-1}$	0.1870	0.0238	CNXNiftyJunior$_{t-1}$	0.1370	0.0283	CNXBank$_{t-1}$	0.1350	0.0804	CNXS&P500$_{t-1}$	0.1050	0.0514
Nifty$_{t-1}$	0.1098[a]	0.0600	Nifty$_{t-1}$	0.1924[a]	0.0600	Nifty$_{t-1}$	0.1581[a]	0.0600	Nifty$_{t-1}$	0.0998	0.0600	Nifty$_{t-1}$	0.1093[a]	0.0600
2005–07	CNXMNC$_t$	Nifty$_t$		CNXMidcap$_t$	Nifty$_t$		CNXNiftyJunior$_t$	Nifty$_t$	2005–07	CNXBank$_t$	Nifty$_t$		CNXS&P500$_t$	Nifty$_t$
CNXMNC$_{t-1}$	0.1140	0.0251	CNXMidcap$_{t-1}$	0.1710	0.0298	CNXNiftyJunior$_{t-1}$	0.1430	0.0511	CNXBank$_{t-1}$	0.1560	0.1103	CNXS&P500$_{t-1}$	0.1170	0.0617
Nifty$_{t-1}$	0.1396[a]	0.0690	Nifty$_{t-1}$	0.1943[a]	0.0690	Nifty$_{t-1}$	0.1740[a]	0.0690	Nifty$_{t-1}$	0.1092	0.0690	Nifty$_{t-1}$	0.1210[a]	0.0690
2008–11	CNXMNC$_t$	Nifty$_t$		CNXMidcap$_t$	Nifty$_t$		CNXNiftyJunior$_t$	Nifty$_t$	2008–11	CNXBank$_t$	Nifty$_t$		CNXS&P500$_t$	Nifty$_t$
CNXMNC$_{t-1}$	0.0680	0.0257	CNXMidcap$_{t-1}$	0.1900	0.0171	CNXNiftyJunior$_{t-1}$	0.1310	0.0148	CNXBank$_{t-1}$	0.1250	0.0653	CNXS&P500$_{t-1}$	0.0960	0.0430
Nifty$_{t-1}$	0.0928[a]	0.0540	Nifty$_{t-1}$	0.1880	0.0540	Nifty$_{t-1}$	0.1480[a]	0.0540	Nifty$_{t-1}$	0.0936	0.0540	Nifty$_{t-1}$	0.1008[a]	0.0540

[a] Indicates that the cross-autocorrelation is higher than the autocorrelation.

Table 3B BSE cross-correlations.

Overall	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$		BSE500$_t$	Sensex$_t$	Overall	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$
Bankex$_{t-1}$	0.1440	0.0870	Dollex200$_{t-1}$	0.1240	0.0615	BSE500$_{t-1}$	0.1130	0.0573	Bankex$_{t-1}$	0.1440	0.0870	Dollex200$_{t-1}$	0.1240	0.0615
Sensex$_{t-1}$	0.1150	0.0760	Sensex$_{t-1}$	0.1310[a]	0.0760	Sensex$_{t-1}$	0.1249[a]	0.0760	Sensex$_{t-1}$	0.1150	0.0760	Sensex$_{t-1}$	0.1310[a]	0.0760
2005–07	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$		BSE500$_t$	Sensex$_t$	2005–07	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$
Bankex$_{t-1}$	0.1700	0.1165	Dollex200$_{t-1}$	0.1070	0.0623	BSE500$_{t-1}$	0.1230	0.0640	Bankex$_{t-1}$	0.1700	0.1165	Dollex200$_{t-1}$	0.1070	0.0623
Sensex$_{t-1}$	0.1222	0.0800	Sensex$_{t-1}$	0.1189[a]	0.0800	Sensex$_{t-1}$	0.1313[a]	0.0800	Sensex$_{t-1}$	0.1222	0.0800	Sensex$_{t-1}$	0.1189[a]	0.0800
2008–11	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$		BSE500$_t$	Sensex$_t$	2008–11	Bankex$_t$	Sensex$_t$		Dollex200$_t$	Sensex$_t$
Bankex$_{t-1}$	0.1320	0.0731	Dollex200$_{t-1}$	0.1260	0.0575	BSE500$_{t-1}$	0.1060	0.0510	Bankex$_{t-1}$	0.1320	0.0731	Dollex200$_{t-1}$	0.1260	0.0575
Sensex$_{t-1}$	0.1099	0.0710	Sensex$_{t-1}$	0.1322[a]	0.0710	Sensex$_{t-1}$	0.1189[a]	0.0710	Sensex$_{t-1}$	0.1099	0.0710	Sensex$_{t-1}$	0.1322[a]	0.0710

[a] Indicates that the cross-autocorrelation is higher than the autocorrelation.

Table 4A The underlying process and the speed of adjustment estimates for NSE indices.

Sample	Speed of adjustment		
	AR (1)	ARMA (1,1)	ARMA (1,*X*)
2005—2011			
Nifty	0.930922	0.931793	0.931202
CNX Bank	0.890147***	0.889638***	0.886744***
CNX MNC	0.923937**	0.927148**	0.925731**
CNX SP500	0.895864***	0.895343***	0.895911***
CNX Midcap	0.835355***	0.827030***	0.833080***
CNX Nifty Junior	0.906118***	0.906527***	0.904788***
2005			
Nifty	0.853018	0.783567**	0.783567**
CNX Bank	0.879573	0.828540*	0.862634
CNX MNC	0.885757	0.879654	0.867685
CNX SP500	0.802362*	0.710770***	0.710770***
CNX Midcap	0.811119*	0.691776***	0.691776***
CNX Nifty Junior	0.869480	0.809423*	0.809423*
2006			
Nifty	0.966746	0.967210	0.990470
CNX Bank	0.855900*	0.848603*	0.844748*
CNX MNC	0.939091	0.935814	0.962142
CNX SP500	0.915063	0.910156	0.927944
CNX Midcap	0.900141	0.851282	0.875580
CNX Nifty Junior	0.956687	0.918565	0.932706
2007			
Nifty	0.879342	0.879139	0.913316
CNX Bank	0.806398**	0.815849**	0.820041**
CNX MNC	0.848895*	0.857814*	0.862790*
CNX SP500	0.848277*	0.849678*	0.891874
CNX Midcap	0.776939**	0.787409**	0.728189***
CNX Nifty Junior	0.883594	0.875365	0.832321**
2008			
Nifty	0.935325	0.938515	0.926303
CNX Bank	0.826888*	0.813849*	0.820601*
CNX MNC	0.842625	0.851991	0.874370
CNX SP500	0.876367	0.892375	0.879586
CNX Midcap	0.749661***	0.782138**	0.749990***
CNX Nifty Junior	0.823613*	0.835958*	0.813716**
2009			
Nifty	0.974658	0.969491	0.968573
CNX Bank	0.821306**	0.821435**	0.843913**
CNX MNC	1.044733	1.015470	1.015470
CNX SP500	0.932170	0.925507	0.945212
CNX Midcap	0.844791**	0.842027**	0.837695**
CNX Nifty Junior	0.877314*	0.876742*	0.858060*
2010			
Nifty	1.088900	1.089677	1.065891
CNX Bank	1.063907	1.052598	1.066476
CNX MNC	0.981669	0.981530	0.964964
CNX SP500	1.057422	1.061879	1.071596
CNX Midcap	0.916242	0.916234	0.908378
CNX Nifty Junior	0.967355	0.968773	0.981672
2011			
Nifty	0.847956	0.840658	0.843520
CNX Bank	0.712975***	0.712261***	0.722475***
CNX MNC	0.863759	0.860562	0.852477
CNX SP500	0.800894**	0.796326**	0.795870**
CNX Midcap	0.759890***	0.764199**	0.747553***
CNX Nifty Junior	0.747584***	0.747778***	0.753776***

*** — Statistically significant from 1 at 1%.
** — Statistically significant from 1 at 5%.
* — Statistically significant from 1 at 10%.
MA (*X*) term is determined using Schwarz Information Criterion.

autocorrelation and contemporaneous correlations have been calculated for each index for the whole period of 2005—2011 and for each year independently. According to Poshakwale and Theobald (2004), the index with the larger market capitalisation should lead the index with the smaller market capitalisation. In a majority of cases it was observed that the index with the large market capitalisation i.e., the Nifty in the case of the NSE indices and the Sensex in the case of the BSE indices, led the other indices. However, in the course of this study three major observations were made, which require further discussion. The lead—lag relationship in the NSE was strong in most indices till the year 2009, which is in consonance with the observation made by Poshakwale and Theobald (2004). In the years 2010 and 2011, this influence weakened. Another observation is that in both markets, this lead—lag pattern was not observed in the bank indices. Also, in the BSE, the Smallcap index does not seem to be led by the Sensex.

Speed of adjustment estimators

The speed of adjustment estimators (AR (1), ARMA (1), and ARMA (1, *X*)) for the indices of the NSE and the BSE are given in Tables 4A and 4B respectively, while the cross-covariance estimator is given in Table 4C. It was observed that the Nifty in the NSE and the Sensex in the BSE led the other indices consistently. The Nifty in the NSE had under-reactions throughout 2005—2011, but these were not statistically significant. Moreover, the speed at which the indices adjust to the information improved during this period. This could be considered as one area of improvement in the market efficiency. Nifty was also resilient to the crisis in the year 2008 and the under-reaction during this year was not statistically significant. The only index that had significant under-reactions among NSE indices was Bank Nifty. The crisis began with the failure of the financial sector firms. Though Indian banks were not directly affected, yet the speed at which banking stocks reacted to the contemporary news in the year 2008 was much lower than it has been in the other years. Similar observations were made for the BSE indices as well. The information adjustment estimator of the Sensex was found to be closer to 1, reflecting speedier adjustments. The Bankex had suffered a setback during the crisis time. All the indices had

Table 4B The underlying process and the speed of adjustment estimates for BSE indices.

Sample	Speed of adjustment		
	AR (1)	ARMA (1,1)	ARMA (1,*X*)
2005—2011			
Sensex	0.917170**	0.917893**	0.916329**
Bankex	0.885449***	0.884758***	0.883114***
Dollex200	0.876336***	0.876065***	0.876833***
BSE500	0.888067***	0.887109***	0.888194***
Midcap	0.813343***	0.805723***	0.807663***
Smallcap	0.721027***	0.709967***	0.717438***
2005			
Sensex	0.857911	0.788272**	0.788272**
Bankex	0.854206	0.790949**	0.842046
Dollex200	0.838250	0.744031***	0.744031***
BSE500	0.804855*	0.715131***	0.715131***
Midcap	0.772383**	0.646058***	0.646058***
Smallcap	0.724584***	0.585106***	0.585106***
2006			
Sensex	0.981960	0.978991	0.973506
Bankex	0.875033	0.861647	0.869878
Dollex200	0.923490	0.915955	0.941738
BSE500	0.934674	0.922532	0.948419
Midcap	0.842492	0.798732*	0.823982*
Smallcap	0.742898***	0.696707***	0.710798***
2007			
Sensex	0.849410*	0.849650*	0.860755*
Bankex	0.796575**	0.810981**	0.801199***
Dollex200	0.833705*	0.835144*	0.795740*
BSE500	0.815811**	0.819358**	0.850847*
Midcap	0.802671**	0.840099**	0.747229***
Smallcap	0.694200**	0.752818***	0.752818***
2008			
Sensex	0.925296	0.911137	0.948493
Bankex	0.830649*	0.815113*	0.827187*
Dollex200	0.858594	0.864021	0.870058
BSE500	0.872347	0.878596	0.877425
Midcap	0.746679***	0.827533*	0.759619***
Smallcap	0.648680***	0.753492**	0.652844***
2009			
Sensex	0.942435	0.937431	0.961469
Bankex	0.809355**	0.811855*	0.827043**
Dollex200	0.869744*	0.862489*	0.889772
BSE500	0.915149	0.910715	0.930241
Midcap	0.810204**	0.811872	0.798933***
Smallcap	0.732271***	0.746897***	0.720868***
2010			
Sensex	1.082182	1.081155	1.102192
Bankex	1.067961	1.053173	1.053173
Dollex200	1.029837	1.030667	1.003061
BSE500	1.059660	1.059777	1.036814
Midcap	0.941851	0.941707	0.930148
Smallcap	0.908000	0.910601	0.940384

Table 4B (*continued*)

Sample	Speed of adjustment		
	AR (1)	ARMA (1,1)	ARMA (1,*X*)
2011			
Sensex	0.933567	0.938260	0.886320
Bankex	0.930989	0.929668	0.867081
Dollex200	0.860842	0.879696	0.837280*
BSE500	0.867159	0.879696	0.806887**
Midcap	0.711893***	0.728574***	0.622954***
Smallcap	0.632171***	0.637658***	0.561201***

*** — Statistically significant from 1 at 1%.
** — Statistically significant from 1 at 5%.
* — Statistically significant from 1 at 10%.
MA (*X*) term is determined using Schwarz Information Criterion.

over-reactions in 2010 on account of the news regarding the crisis in the European Union and the consequent slowdown in the Indian economy. The Smallcap index in NSE and the Midcap index in BSE had statistically significant under-reactions throughout the study period indicating and confirming the expectations spelt out in the literature that large cap stocks adjust to the information faster.

The MA (*X*) component captures the effects of thin trading in the ARMA (1, *X*) model. However, unlike the observations made by Poshakwale and Theobald (2004) where the ARMA (1, *X*) estimates move away from the ARMA (1, 1) model closer to 1, this was not predominant in the indices chosen in this study. A reason for this could be the fact that the constituents of all indices were frequently traded, thus negating the effects of thin trading. According to Poshakwale and Theobald (2004), prior to 1994, investors outside Mumbai did not have adequate access to the stock market. This scenario changed post 1994, with the economic liberalisation in full swing and the establishment of the NSE. More investors could now invest in the stock market. It is therefore quite logical that during the study period, the problem of thin trading was not as acute as it was when Poshakwale and Theobald (2004) conducted their study.

While computing the cross-covariance estimators, the Nifty in the case of the NSE, and the Sensex in the case of the BSE, were considered as reference indices to compare the speed of other observed indices. Each of the other indices has been paired with a reference index to confirm the relative speed at which the observed index adjusts. In the case of NSE indices, the Nifty Junior and the MNC indices had the highest speed of adjustment estimators on an average, after the Nifty. The CNX Bank index also had high estimator values. In the BSE, the Bankex had the second highest values of estimators on an average, after the Sensex. In the years 2010 and 2011 the banking indices have shown a higher speed of adjustment in the cross-covariance estimator as well. The midcap indices of both exchanges also had comparable slower speed estimator values. The Smallcap index of the BSE had the least estimator values.

According to Chordia and Swaminathan (2000), Poshakwale and Theobald (2004), and Chiang, Nelling, and Tan (2008) large stocks lead small stocks. Large stocks tend to be traded more frequently and are more closely followed by analysts. Therefore the speed with which they absorb new information is much faster than small stocks.

Table 4C The cross-covariance speed of adjustment estimator.

Sample	Cross-covariance speed of adjustment estimator						
2005—2011							
Bankex	0.871114	Sensex	0.902516	CNX Bank	0.885109	Nifty	0.907426
Dollex200	0.864479	Sensex	0.936399	CNX MNC	0.874430	Nifty	0.968837
BSE500	0.872517	Sensex	0.941516	CNX SP500	0.889032	Nifty	0.947873
Midcap	0.739369	Sensex	0.979704	CNX Midcap	0.777799	Nifty	0.972476
Smallcap	0.673335	Sensex	0.988461	CNX Nifty Junior	0.822068	Nifty	0.968178
2005—07							
Bankex	0.853751	Sensex	0.860560	CNX Bank	0.865679	Nifty	0.864296
Dollex200	0.876855	Sensex	0.935513	CNX MNC	0.839151	Nifty	0.971128
BSE500	0.865211	Sensex	0.934306	CNX SP500	0.876617	Nifty	0.937495
Midcap	0.749208	Sensex	0.973867	CNX Midcap	0.772024	Nifty	0.965058
Smallcap	0.714316	Sensex	0.994658	CNX Nifty Junior	0.795223	Nifty	0.939848
2008—11							
Bankex	0.879858	Sensex	0.920109	CNX Bank	0.895185	Nifty	0.926830
Dollex200	0.863310	Sensex	0.940518	CNX MNC	0.894697	Nifty	0.970823
BSE500	0.878950	Sensex	0.948096	CNX SP500	0.897775	Nifty	0.955847
Midcap	0.739461	Sensex	0.987437	CNX Midcap	0.784671	Nifty	0.980404
Smallcap	0.659682	Sensex	0.992833	CNX Nifty Junior	0.836619	Nifty	0.983617

Therefore indices that consist of large cap stocks will lead those whose constituents are small cap stocks.

The MNCs, banks and other stocks with large market capitalisation were faster in absorbing the information both within and outside the country. International information might not have had a huge impact on the small and to a certain extent, midcap stocks. Hence, the speed at which they absorbed information was comparatively slower.

Bank indices are very sensitive to macroeconomic changes of any kind. Bank stocks would reflect the confidence of the investors in an economy. The impact of any shock on any sector is felt on the banks in varying degrees of severity. Information adjustment is more pronounced in the bank indices when compared to others, except the two flagship indices.

Conclusion

In the case of an efficient market, the information gets assimilated almost instantaneously in the stock price and therefore this information would not be of use for a person to take a decision with regard to the future movement of the price of the security. The speed of information adjustment can be defined as the speed at which a stock price moves towards its intrinsic value from its observed price.

The last decade of the twentieth century was a time of great change in the Indian economy when it opened up to foreign players. The process also stimulated domestic trading on the stock markets. The stock markets introduced new products and trading in derivatives. The National Stock Exchange that began operations in 1992 took share trading from the "ivory tower" of Dalal Street to the masses of India. The corporate governance reforms resulted in improved quality and quantity of information disclosures in the Indian markets. The impact of these reforms on creating an efficient market environment is an interesting research issue that requires investigation in India.

This research measured the speed of information adjustment in various indices of the Indian stock market. The speed of information adjustment has been measured for BSE and NSE indices with multiple characteristics in order to identify the indices that adjust faster to the information. Further, the lead—lag relationships between different indices of two different Indian stock exchanges, the BSE and the NSE, have been analysed. Cross-covariance ratio, ARMA (1, 1), ARMA (1, X) and AR models were used to estimate speed coefficients. All the alternate measures of estimators have confirmed that the Nifty in the NSE and the Sensex in the BSE lead the other indices in the market. The bank index was found to be an independent index that was not led by the benchmark indices, the Sensex and the Nifty. The Nifty and the Sensex also adjust to the information faster than other indices. Clearly, the indices with large capitalisation led the indices with small capitalisation till the year 2009; but this pattern was disturbed in the years 2010 and 2011, especially by banking stocks. The market also showed evidence of under-reaction till the year 2009 and over-reaction in the years 2010 and 2011. The ARMA (1, X) model in which the MA (X) component was used to capture the effects of thin trading showed that thin trading has reduced considerably, which is quite natural considering the nature of the constituents of the indices in the study and the state of the Indian markets as a whole.

The results of this study provide useful insights to academicians, policy makers, regulators, and investors. An increase in the speed at which information gets adjusted into market indices has been observed, indicating improved informational efficiency of the Indian stock markets as a result of ongoing market reforms in India. The results offer very positive feedback to the policy makers and market regulators.

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