

# DEMYSTIFYING THE DARK SIDE OF TECHNOLOGY IN INDIAN STOCK EXCHANGES A COMPARATIVE ANALYSIS BETWEEN NSE AND BSE

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## ABSTRACT

***Purpose:** In the light of the globalization of capital markets and the new opportunities arising for stock market evolution in recent years, the main objective of this paper is to empirically compare two time periods (Pre and Post colocation) involving market innovation for India's two major stock exchanges National Stock Exchange (NSE) and Bombay Stock Exchange (BSE). The study also aims to find if the relative attractiveness of NSE with respect to BSE has changed due to financial market innovation.*

***Design/technique/Methodology:** The unmatched two-sample t-test with unequal variance was used to compare listing and trading competition variables of NSE and BSE over two time periods (Pre and Post colocation). Further, Analysis of Variance (ANOVA) was applied to check the robustness of the results. For this purpose, the study's period was bifurcated into three periods (i.e. Pre colocation, during scam, and Post colocation).*

**Results:** *The results of the t-test and ANOVA suggest a significant difference between the distinct periods of the study in both the listing as trading variables. Hence, there is a considerable difference in the attractiveness of both NSE and BSE throughout the study.*

**Originality/Value:** *The Indian Stock Market has witnessed a paradigm shift in technology. This shift in the intensity of Algorithmic Trading can be attributed to the innovation of colocation facility. Therefore, based on extant literature and collection of factual information, this study is amongst the earliest to empirically highlight the difference of attractiveness between NSE and BSE in pre and post colocation.*

**Implications:** *The study is helpful for regulators to understand the competition between NSE and BSE because regulator (SEBI) continually strives to operate in a fair market environment. The trading attractiveness of NSE is less than BSE in the post colocation. Policymakers and financial advisors can use this information to make their suggestions accordingly.*

**Keywords:** High Frequency Trading, Colocation facility, Colocation Scam, Attractiveness of NSE and BSE.

## INTRODUCTION

Stock exchanges have played a pivotal role in the development of the economy in India. They have provided a platform to disseminate information and raise capital. The globalization of the capital market has provided several opportunities for stock market evolution in recent times. Indian capital market constitutes of two significant exchanges: National Stock Exchange (NSE) and Bombay Stock Exchange (BSE), where BSE is the oldest exchange of the country established in 1875. However, NSE was incepted in 1992 as the first demutualized electronic exchange of the country. It was the first in the country to provide a modern and fully automated screen-based electronic trading system that made transactions much easier and transparent for the traders compared to BSE, which followed the old traditional floor-based ‘Out Cry’ trading method.

Regarding transaction intensity, the NSE of India is amongst the top-ranked equity trade markets across the globe. It enjoys the most significant share of equity market activities in India. NSE and BSE have always been competitors to each other as they are in the same field. This competition could be listing (Company perspective) and trading (Investor’s perspective). This healthy competition brings about a race to grab more firm listings and more trading by investors to be the leader in the financial market. NSE is more known for timely up-gradation of new technology, thus enjoying the first-mover advantage majorly because of this reason. In India, the technological innovation of colocation was introduced in 2010 to reduce the latency or time taken to disseminate information from the stock exchanges. Colocation essentially means a mechanism wherein the traders deploy different advanced technologies and locate the systems near the trading venue to reduce the latency of orders and enjoy the extra advantage of the facility. As this facility was provided only to the members exclusively, they managed to place their servers in the exchange’s premises for a certain fee. This made the traders place their trade

orders with a lightning speed of microseconds. This proved to be a great advantage in placing orders and profitability because of the faster transaction process than those who did not have access to the colocation facility. Certain members associated with High-Frequency Traders (HFT) teamed up. They worked for about four years, 2010 to 2014, overriding all the rules and regulations imposed by SEBI, the market regulator in India. This created unrest amongst the other traders in India. This also compelled SEBI to take legal action against NSE. As a result, NSE had to pay heavy charges.

NSE faced severe consequences for being involved in the colocation scam. Hampering of the image has been one of the significant consequences, apart from being barred from an IPO for six months and paying heavy charges for the negligence of fiduciary duties. As such, the dynamics of the capital market in India has witnessed a drastic change, due to innovations. The traders and firms prefer NSE. Therefore, it becomes of paramount importance to study the post scam scenario. On the other hand, BSE being the oldest exchange body in India has been consistent and successful in maintaining and building a fair image over many decades now. It has also managed to be involved in minimal controversies as compared to NSE. It is well established that NSE was a preferred medium of trading in comparison to BSE (NSE India.in), before the colocation scam. However, it is essential to understand the changed scenario in terms of the post scam effect on the attractiveness of both the major exchange bodies in India.

In this paper, we explore the attractiveness of two major stock exchanges of India in the context of listing and trading perspectives before and after colocation. We employ various proxies to measure the exchange's listing attractiveness, such as total listings, new listing, and capital raising. Similarly, to capture the trading attractiveness, we use liquidity, price discovery, dividend. With this objective of exploring the two parameters of stock exchanges, we contribute to the existing literature by providing evidence that NSE is more prone to innovations like colocation facilities than BSE. Thus, it is favourable for traders who receive such facilities than firms that seek to get listed. Another exciting fact our study differs from most of the literature is that the listing attractiveness of NSE is increased except for one variable for visibility. On the other hand, trading attractiveness is decreased except for one variable that is for price discovery. So, we see that overall "*colocation*" has, on average, increased the relative listing attractiveness of NSE and decreased the relative trading attractiveness of NSE, respectively.

## Motivation

According to an article published by Money Control in 2019, there are great articles related to colocation facilities in Indian exchanges, but none of these has empirically tested their attractiveness. Therefore, in this article, we strive to empirically examine the attractiveness of the two major exchange houses in the pre-and post-colocation periods.

As an emerging market with minor investor protection and several scams, India brings us to study the attractiveness of the Indian exchanges, Abdulraheem (2009). An Analysis of Financial Fraud through PNB Bank Scam and its technical Implications. As most studies are related to the developed market, this paper is the first to study the emerging market.

## Review of Literature

It investigates the factors that make specific stock markets attractive compared to the others from two prisms- 1) Investors and 2) Firms. He focused on the performance of stock exchange houses from an international point of view by combining the competitive aspects of trading and listing variables. His study considers panel data for the world's largest 45 stock exchanges, as per the World Federation of Exchanges. The results of the analysis showcase that exchange houses that are frontiers in listing competition variables do not implicitly attract the investors to trade. Similarly, exchange houses which are frontiers in trading competition may not be attractive in terms of listing. Finally, the author developed a competition matrix to aid the management authorities of the stock exchanges around the globe for two reasons- 1) Strategically position themselves in the industry. 2) Provide directions for continuous improvement of efficiency.

The increase in competition has led to mergers, technological agreements among existing exchanges, price wars, takeovers, and new exchanges, within the same country. This is mainly due to the transformation of the securities markets in Europe. On similar lines, in his study, on the competition among exchanges and the possibility of strategic interaction among them, Noia (2001), describes the competition among exchanges by examining network externality. The study compares a model of “*incompatibility*” i.e., exchanges competing against one another to that of the “*complete compatibility*” i.e., where exchanges agree on implicit merger and reciprocal remote access. Thus, exchanges can be considered “networks in which the number of customers, the higher the utility for everyone” (Economides, 1993 and 1995). Other things remaining constant, firms want to replicate and be listed where other firms are listed (the direct-network effect), especially where many intermediaries trade (the cross-network effect). This is because of the availability of better liquidity in the market.

In the past few years, stock exchanges have been observed to rapidly diversify their operations into related areas such as software sales, derivatives trading and post-trading services. This particular trend is more prominent amongst the trading venues which are profit-oriented. While the endeavour for diversification is expected to be determined by the attractiveness of available investment opportunities, it remains unanswered whether a particular integration activity is also efficient. This is considered from both perspectives i.e., the welfare of the society and the exchanges houses. Serifsoy (2007) investigated “*whether stock exchanges that pursue certain integration strategies operate more efficiently*”. This study suggests that exchanges that diversify into related activities are less efficient than exchanges that remain focused on the cash market (in most cases). There is no specific evidence that vertically integrated exchanges are more efficient. However, they seem to possess a considerably stronger factor productivity growth than most other business models. The paper works on the presumption that, integration activity comes at the cost of increased operational complexity. This outweighs the potential synergies between related activities and hence, leads to certain technical inefficiencies.

Another study by Serifsoy (2008) focuses on determining whether demutualized stock exchanges possess a stronger operative performance than mutual exchanges. Furthermore, the

study also analyzed whether outsider-owned exchanges perform better in this respect than demutualized but broker-owned exchanges. By operationalizing a balanced (no missing values: combined of time series and cross sectional) panel data collection of 28 stock exchanges the effects of demutualization and outsider ownership on the operative performance of stock exchanges were examined. The study finds enough evidence to conclude that demutualized exchanges exhibit higher technical efficiency than mutual. However, the extent to which productivity growth is concerned, they perform relatively poorly. The study finds no evidence that publicly listed exchanges possess higher efficiency and productivity values than demutualized exchanges with a customer-dominated structure.

Krishnamurti et al. (2003) make an empirical contribution in this arena by comparing the market quality of the Bombay Stock Exchange, a mutual, with that of the National Stock Exchange, a demutualized trading venue. They propose that demutualized exchanges are superior to mutualize in governance.

In his study, Sanusi (2018) explored the operational activities of one of the major exchanges of the UK, ie, the London stock exchange (LSE), in the twenty-first century. This become achieved so that you can offer a comprehensive view of its operational transparency and competitiveness; the opposition amongst its marketplace members, and the way it competes with different developed stock exchanges around the sector and examines opposition from both outdoor and within the change by using specializing in the extent of restrictions on marketplace individuals; flexibility in regulations; honest pricing; transaction costs stages; sports of brokers, institutional traders and makers in the market; commonly the equality of opportunity and transparency provided to each participant. The key factors that decorate the competitive attractiveness of the London stock exchange (LSE) are the ongoing generation which includes transformation, globalization and flexibility in selecting the rules under which various members of the market can operate. In the era of transformation, the exchange has implemented different automatic buying and selling structures, successfully facilitating an external competitive advantage. On a similar line, used difference-in-difference regression to estimate the causal impact of Algorithmic Trading (AT) on market quality by addressing the introduction of colocation. These findings suggest that AT improves market quality. Financial market innovation (colocation) has a significant positive effect on the transaction costs, volatility, and order imbalance but not all of the other measures of market quality (depth measure), and the liquidity risk is decreased with higher AT.

An important innovation in the Indian Stock market was introducing colocation facilities at the NSE in early 2010. It suggested that the earlier technology was a hurdle to effective Algorithmic trading (AT). Colocation brought about a significant change in the intensity of AT in India. As a result, latency dropped from 10-30 ms (milliseconds) to 2-6 ms post introduction of colocation facility. This gave a significant edge to the traders who established automated systems in the colocation facility. The Indian Stock Market, therefore, witnessed a clear paradigm shift in technology on a well-identified date. This shift in the intensity of AT can be attributed to the innovation of colocation facilities. Riordan and Storckenmaier (2012) investigate

introducing a new trading system that impacts market liquidity and price discovery. Xetra 8.0 was introduced in the German stock market (Deutsche Boerse) on 23rd April 2007, which accelerated trading speed in the German stock market (Deutsche Boerse). The result of this study suggests that increasing speed in the stock market leads to improvement in small- and medium Sized stocks' liquidity and an increase in price efficiency.

As market fairness and integrity is an important aspect of the healthy stock market performance Angel et al. (2013) explored how advancement in technology brings inequality among the stock market participants. Their study highlights, how equality can be brought to make a fair marketplace for all other participants besides high-frequency traders (HFT). Their study suggests how one can bring the fairness in the stock market when, someone have technological advancement by using certain stock market mechanism.

Similarly, Shefrin et al. (1993) describe market regulations, which are necessary for the operationalization of the stock market like ethics, market fairness, and market efficiency. It is a belief for the world of regulations that financial fairness guarantees financial market effectiveness. This study suggests how there is a contest of strength between market fairness and economic efficiency demonstrated by six major regulations. Similarly, Heath (2010) explains in his book, what are the major issues in financial service, finance theory, financial markets, and financial management. By paying special attention to market fairness and efficiency in financial services.

Brogaard et al. (2015) investigate whether the optional upgradation in colocation or advancement in speed of trading beneficial for market liquidity or not. Their results suggest that the increment in speed have positive impact on market liquidity. So, upgradation in colocation at NASDAQ OMX Stockholm have improved the liquidity of the Swedish equity market. Jawed and Chakrabarti (2018) examine the recent innovations, particularly algorithmic trading in the Indian stock market, impact productive efficiency. They measure whether the introduction of colocation trading changes the speed of information adjustment or not. Their result suggests a significant improvement in the productive efficiency, especially for mid-cap and small-cap indices in India. Finally, Aitken et al. (2018) examined the impact of escalating development in algorithmic trading (AT) on market fairness and efficiency in developed economy i.e., London stock exchange and NYSE Euronext Paris. By building a systems estimation model (SEM), they have shown how greater involvement of AT reduces information breaches and increases the trading efficiency in the London stock exchange and NYSE Euronext Paris.

Therefore, in the light of the extant literature and collection of factual information mentioned above, this study seeks to determine the level of attractiveness between NSE and BSE in pre and post colocation. It is essential to understand the changed scenario as there is a lacuna of empirical testing to form a generalized base for further research in India.

The rest of the paper proceeds as follows: The following section describes our objective and hypothesis formation. Section-3 provides the introduction of our research model. Section-4 presents the research methodology. Section-5 provides the analysis of data variables and results,

and in section-6, we provide robustness check. The final section concludes the paper with our conclusion and remarks.

## Hypothesis formation

It has been found that in many countries that financial market innovations have an impact on exchanges in terms of their attractiveness, particularly for listing competition variables and trading competition variables. Our study's primary objective is to empirically examine the effect of the market innovation on the relative attractiveness of India's two major stock exchange NSE and BSE. For that, we first estimate and examine the level of attractiveness of NSE and BSE and test if they are different from each other. Then we investigate if there is any impact of colocation on attractiveness of the two Indian exchanges. With time, the economy and its exchanges are expected to develop and be more attractive to investors. Hence simply examining the change in the attractiveness of individual exchanges might not be conclusive. Therefore, we compare the difference in the relative attractiveness of NSE with respect to BSE after the introduction of colocation to find if NSE has gained differently due to the introduction of colocation compared to BSE. This difference-in-difference approach helps eliminate the bias in results created due to any upwards trends induced over time.

It has been found that in many countries, financial market innovations impact exchanges in terms of their attractiveness, particularly for listing competition variables and trading competition variables. The objective of the present study is to see how colocation has impacted the attractiveness of the two major Indian stock exchanges. First, we check the attractiveness of NSE in terms of listing and trading is different from BSE. Or whether they are the same based on two parameters, namely listing attractiveness and trading attractiveness.

*H<sub>1a</sub>: The listing attractiveness of NSE and BSE are different over time.*

*H<sub>1b</sub>: The trading attractiveness of NSE and BSE are different over time.*

Further, in the second set of hypotheses, we check if the attractiveness of NSE in terms of listing and trading is the same as BSE. If implemented fairly and effectively, market innovations should lead to higher benefits for its members and participants. Hence should lead to greater attractiveness for the exchange. But sometimes, market innovations are misused to benefit only a section of participants at the cost of others. It creates negative externalities and systemic risks that depletes participants' confidence and hence lead to lower attractiveness of the exchanges. Therefore how it will impact the attractiveness of the Indian market is an empirical question that is yet to be answered. Hence, we examine if the listing and trading attractiveness of NSE and BSE changes due to introduction of colocation and if so how.

*H<sub>2a</sub>: The attractiveness of NSE with respect to BSE is different in terms of listing variables.*

*H<sub>2b</sub>: The attractiveness of NSE with respect to BSE is different in terms of trading variables.*

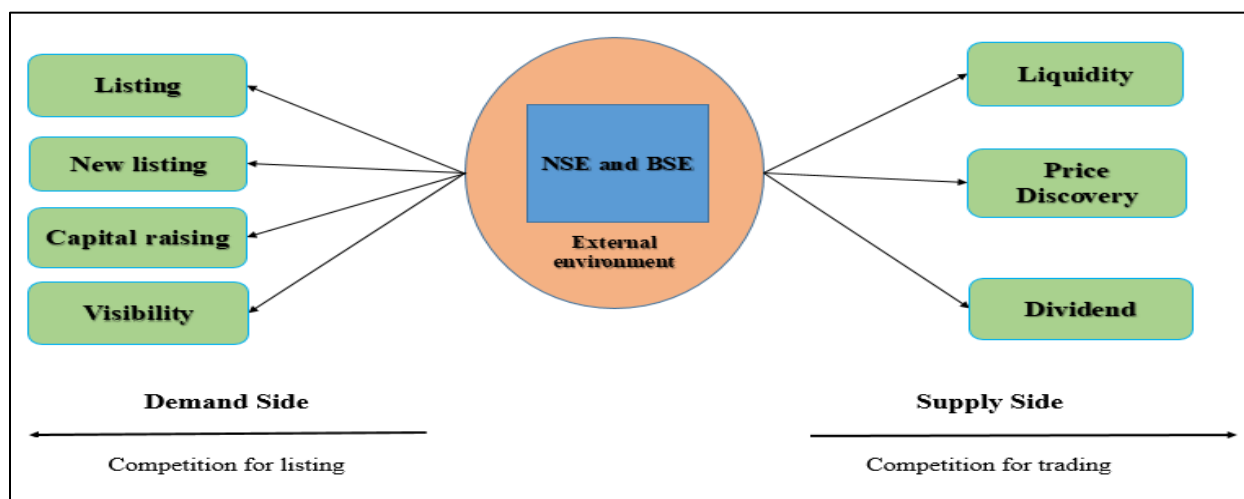
Lastly, we compare the change in the relative attractiveness of NSE with respect to BSE after the introduction of colocation using a difference-in-difference approach to eliminate any trend induced bias. Hence, in our third set of hypotheses, we check the impact of market innovation and the relative of the attractiveness of NSE with respect to BSE.

**H3a:** Colocation has impact on the relative listing attractiveness of NSE with respect to BSE.

**H3b:** Colocation has no impact on the relative trading attractiveness of NSE with respect to BSE.

**Research Model and Data Variables**

The present study integrates the competition-related variables in a methodical manner Fig-1 represents two sides of the exchange attractiveness: the capital demand and the supply. The demand part includes the factors for competition in terms of the listing, like new listing, listing, visibility, and capital raising. For supply, the factors for competition in terms of trading, are dividend, price discovery and liquidity. Practically, when exchange houses offer a listing, they also provide additional services like monitoring trade transactions, publicity or advertisement, liquidity, and ATIF, i.e., after-trade information facilities.



**FIGURE 1  
MODEL FOR LISTING AND TRADING COMPETITION OF NSE AND BSE**

<b>Table 1</b>			
<b>PANEL –A PROVIDES THE DEFINITIONS AND PROXY AND ABBREVIATION OF LISTING COMPETITION VARIABLES, AND PANEL-B DESCRIBES THE DEFINITIONS AND PROXY AND ABBREVIATION OF TRADING COMPETITION VARIABLES</b>			
Panel-A			



<b>Listing Variables</b>	<b>Definition</b>	<b>Proxy</b>	<b>Abbreviation</b>
Listing	Number of companies that are listed in both the exchange BSE and NSE.	Number of listed companies in both the exchanges.	LIST
New listing	Total number of new listed companies for both exchanges BSE and NSE for this study period.	Number of new listed companies in both the exchanges	NEW
Capital raising	The PER is calculated by dividing the market capitalization by Profit after tax (PAT) of Exchanges BSE and NSE.	Mean of price earnings ratios.	PER
Visibility	Market capitalization of the stock exchanges BSE and NSE is considered as SIZE.	Size of the market.	SIZE
Panel-B			
Trading Variables	Definition	Proxy	Abbreviation
Liquidity	The turnover velocity is calculated by dividing the turnover of domestic shares by their market capitalization.	Turnover velocity	TURNOVER
Price discovery	The number of trades is representative of the actual number of transactions occurred during the period on both exchanges.	Total number of trades	TRADES
Dividend	The dividend yield is calculated by dividing the total dividends paid by the domestic companies by their market capitalization.	Dividend yield	DIVIDENDS

The definitions, abbreviations and sources of data variables for listing along with trading competition are represented in Tables 1 & 2.

L <sub>1B</sub>	LIST	1/100
L <sub>2B</sub>	NEW	None
L <sub>3B</sub>	PER	1/10
L <sub>4B</sub>	SIZE (mn)	1/1000000
T <sub>1B</sub>	TURNOVER	*10
T <sub>2B</sub>	TRADES	1/10000
T <sub>3B</sub>	DIVIDEND	*1000

The sample of the study includes cent-percent of the firms listed in the two major exchange of India NSE and BSE. The study is divided into three stages. In the first we compared the pre-colocation scenario for seven years (from 2003-2009) for both the exchanges bodies. In the second stage we compared the post-colocation scenario for ten years (from 2010-2019) for both the exchanges bodies. In the third stage we compared the pre-post-co-location scenario for seventeen years (from 2003-2019).

The study considered exchange-specific performance at all the stages. Four criteria (new listings, listing visibility & capital raising) were considered with respect to listing whereas, three criteria (price discovery, liquidity & dividend) were considered with respect to trading. The

criteria considered in the study were consistent with the study conducted by Lo, (2013). The data has been extracted from World Federation of Exchanges (WFE).

## Research Methodology

The methodology operationalized in this study is the unmatched sample t test with unequal variance, represented in the following equation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where  $\bar{x}_1$  is a mean value of attractiveness of NSE and  $\bar{x}_2$  is the mean value of attractiveness of BSE.  $S^2_1$  sample variance of NSE and  $S^2_2$  sample variance of BSE, where  $n_1$  is sample collected for NSE and  $n_2$  is sample collected for BSE.

## Data Analysis and Results

In order to test to proposed hypothesis of our study we use t test for each listing as well as trading competition variables of NSE and BSE. We conducted a threefold analysis, namely, 1. Comparing BSE and NSE attractiveness for pre-colocation period (2003-09), 2. Comparing BSE and NSE attractiveness for post-colocation period (2010-19) and 3. We finally compared relative attractiveness of BSE and NSE for the pre- and post-co-location period. *t* test is most applicable in this case as our objective is to two compare two unmatched samples. Next, we share the results of our analysis, post applying the t-test.

Summary statistics of the data is represented in Tables 3 & 4.

Variables	L <sub>1N</sub>	L <sub>2N</sub>	L <sub>3N</sub>	L <sub>4N</sub>	L <sub>1B</sub>	L <sub>2B</sub>	L <sub>3B</sub>	L <sub>4B</sub>
Mean	14.84	4.51	26.42	66.95	51.97	5.99	59.68	68.79
Median	15.92	3.00	22.60	61.10	51.13	6.00	54.47	63.38
Maximum	19.55	23.00	67.33	157.31	59.86	22.00	120.54	159.21
Minimum	8.10	0.00	8.05	4.89	38.87	0.00	21.39	5.71
Std. Dev.	3.46	4.78	12.36	42.66	3.85	3.92	20.80	42.79
Skewness	-0.49	1.12	1.43	0.49	0.11	0.94	0.85	0.47
Kurtosis	-1.04	0.88	2.08	-0.74	-0.03	1.25	0.52	-0.74
Observations	202	202	202	202	202	202	202	202
<i>t</i> value	60.95	13.40	30.37	22.30	192.08	21.69	40.78	22.85
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The descriptive statistics show that on an average, BSE is more attractive than NSE in terms of listing competition variables.

Variables	T <sub>1N</sub>	T <sub>2N</sub>	T <sub>3N</sub>	T <sub>1B</sub>	T <sub>2B</sub>	T <sub>3B</sub>
Mean	6.42	12.41	1.40	1.96	2.84	0.66
Median	5.67	12.23	1.28	1.23	2.69	0.61
Maximum	15.32	28.85	4.02	6.52	6.56	1.70
Minimum	3.35	2.99	0.66	0.37	0.23	0.27
Std. Dev.	2.48	6.10	0.54	1.46	0.99	0.23
Skewness	1.47	0.39	2.58	0.85	0.86	2.07
Kurtosis	1.82	-0.33	8.51	-0.23	1.16	5.87
Observations	202	202	202	202	202	202
<i>t</i> value	36.72	28.88	37.13	19.01	40.91	40.31
p value	0.00	0.00	0.00	0.00	0.00	0.00

The descriptive statistics show that on an average, NSE is more attractive than BSE in terms of trading competition variables.

Our first intention was to compare the attractiveness of both the NSE and BSE over time. Therefore, initially we did this in terms of listing competition variables only. The comparative mean analysis of the NSE pre-colocation panel was significantly different from that of the post-colocation at 1% of significance level. The output of the *t* test suggested that the listing attractiveness of NSE has been increased in the post-colocation. The same was found in terms of BSE as well. Thus, we found enough statistical evidence to support hypotheses 1a.

Further to check the attractiveness over time we also compare the trading competition variables. The comparative mean analysis of the NSE pre-colocation panel was significantly different from that of the post-colocation at 1% of significance. The output of the *t* test suggested that the trading attractiveness of NSE has been decreased for two trading variables T1 (liquidity) and T3 (dividend) in the post-colocation and increased in T2 (price discovery). The same was found in terms of BSE as well. Thus, we found enough statistical evidence to support hypotheses 1b Tables 5 & 6.

Variables	L <sub>1N</sub>	L <sub>2N</sub>	L <sub>3N</sub>	L <sub>4N</sub>	L <sub>1B</sub>	L <sub>2B</sub>	L <sub>3B</sub>	L <sub>4B</sub>
	Panel A: Pre-CoLo							
Mean	11.29	2.24	18.46	28.07	49.93	5.93	48.11	30.08
Observations	84	84	84	84	84	84	84	84
<i>t</i> value	49.00	5.63	29.87	15.70	143.01	17.31	30.42	15.74
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Panel B: Post-CoLo							

Mean	17.37	6.12	32.09	94.63	53.42	6.03	67.92	96.34
Observations	118	118	118	118	118	118	118	118
<i>t</i> value	89.59	14.50	68.63	58.12	160.71	18.04	59.80	56.73
p value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Panel C: PostCoLo-PreCoLo								
Mean diff.	6.09	3.88	13.63	66.56	3.49	0.10	19.80	66.26
<i>t</i> value	20.22	6.69	17.60	27.53	7.23	0.22	10.17	25.91
p value	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00

Table 6 TRADING ATTRACTIVENESS OF EXCHANGES OVER TIME						
Variables	T <sub>1N</sub>	T <sub>2N</sub>	T <sub>3N</sub>	T <sub>1B</sub>	T <sub>2B</sub>	T <sub>3B</sub>
Panel A: Pre-CoLo						
Mean	8.59	7.39	1.65	3.49	2.42	0.71
Observations	84	84	84	84	84	84
<i>t</i> value	32.14	17.36	20.50	33.08	20.33	19.12
p value	0.00	0.00	0.00	0.00	0.00	0.00
Panel B: Post-CoLo						
Mean	4.87	15.97	1.23	0.87	3.14	0.63
Observations	118	118	118	118	118	118
<i>t</i> value	26.73	43.50	30.77	10.02	26.25	31.72
p value	0.00	0.00	0.00	0.00	0.00	0.00
Panel C: PostCoLo-PreCoLo						
Mean diff.	-3.72	8.58	-0.42	-2.62	0.72	-0.07
<i>t</i> value	-11.50	15.26	-4.63	-19.16	4.26	-1.77
p value	0.00	0.00	0.00	0.00	0.00	0.03

In order to test our second set of hypotheses where we intended to check relativity of attractiveness of the listing variables between NSE and BSE. We have to treat the panel data in a different manner. In the first step we took out the difference between the mean values of each listing variables of NSE and BSE for entire period. We then interpreted the results in terms of the difference in the mean values. The negative difference values as suggested in Table 4 indicate that BSE is leading in all the four listing completion variables in pre-colocation period. Hence the hypotheses 2a are evidently supported.

Similarly, we took out the difference between the mean values of each trading variables of NSE and BSE. We then interpreted the results in terms of the difference in the mean values. The positive difference values as suggested in Table 5 indicate that NSE is leading in all the three trading competition variables in pre-colocation period. Hence the Hypotheses 2a is evidently supported. This is an interesting finding as there is lacuna of research in this area Tables 7 & 8.

Variables	L <sub>1N-B</sub>	L <sub>2N-B</sub>	L <sub>3N-B</sub>	L <sub>4N-B</sub>
Mean diff.	-37.12	-1.48	-33.26	-1.84
Observations	202	202	202	202
<i>t</i> value	-127.57	-4.80	-51.67	-21.91
p value	0.00	0.00	0.00	0.00

Variables	T <sub>1N-B</sub>	T <sub>2N-B</sub>	T <sub>3N-B</sub>
Mean diff.	4.46	9.57	0.74
Observations	202	202	202
<i>t</i> value	47.56	23.32	32.57
p value	0.00	0.00	0.00

In order to test our third set of hypotheses where we intended to check the difference in the attractiveness in listing in terms of pre- and post-co-location period. We use difference-in-difference (DID) approach to examine the magnitude of the difference of the attractiveness. The difference in the mean value suggests that L1 (Listing) and L2 (New listing) is significantly increasing, L3 (Capital raising) is significantly decreasing and the difference in mean values of L4 (Visibility) was found to be insignificant, as represented in Table 5. Therefore, hypothesis 3a was partially supported, as one of the listing variables is not significantly different.

Further, we check the difference in the attractiveness in trading in terms of pre and post colocation period. The difference in the mean value suggests that T1 (liquidity) and T3 (dividend yield) is significantly decreasing and T2 (price discovery) is significantly increasing as represented in Table 6. Therefore, hypothesis 3b was evidently supported Tables 9 & 10.

Variables	Panel B: PreCoLo			
	L <sub>1N-B</sub>	L <sub>2N-B</sub>	L <sub>3N-B</sub>	L <sub>4N-B</sub>
Mean diff.	-38.64	-3.69	-29.66	-2.02
Observations	84.00	84.00	84.00	84.00
<i>t</i> value	-77.35	-7.70	-30.29	-15.09
p value	0.00	0.00	0.00	0.00
Panel C: PostCoLo				

Mean diff.	-36.04	0.09	-35.83	-1.71
Observations	118.00	118.00	118.00	118.00
t value	-129.31	0.20	-51.49	-16.05
p value	0.00	0.27	0.00	0.00
Mean diff.	2.60	3.77	-6.17	0.31
t value	4.55	5.93	-5.14	1.80
p value	0.00	0.00	0.00	0.04

<b>Table 10</b>			
<b>IMPACT OF COLOCATION ON RELATIVE TRADING ATTRACTIVENESS OF NSE WITH RESPECT TO BSE</b>			
Panel B: PreCoLo			
Variables	T <sub>1N-B</sub>	T <sub>2N-B</sub>	T <sub>3N-B</sub>
Mean diff.	5.10	4.97	0.94
Observations	84.00	84.00	84.00
t value	27.58	14.16	21.19
p value	0.00	0.00	0.00
Panel C: PostCoLo			
Mean diff.	4.00	12.83	0.60
Observations	118.00	118.00	118.00
t value	33.89	44.82	27.91
p value	0.00	0.00	0.00
Mean diff.	-1.10	7.86	-0.34
t value	-5.02	17.35	-6.93
p value	0.00	0.00	0.00

In 2015 a scam in colocation was revealed<sup>1</sup>. This scam revealed a number of negative aspects about the utility and operationalization of colocation technology<sup>5</sup>. Reports also reveal that the duration of the scam was from 2010 to 2013, which is four years<sup>6</sup>. Owing to the sensitivity, longitude of time and the degree of scam, we cannot ignore this period. Therefore, after ascertaining a clear and significant difference between the pre and post colocation period we moved towards the inclusion of the scam period separately in our study. Thereby, the span of the study was divided into three time periods for a better visibility. These periods were pre-collocation, during the scam and post colocation. When comparing the means for more than two samples, Analysis of Variance (ANOVA) is suggested to postulate most accurate results, therefore in the next part of our study we compare all the variable for Listing and Trading, using ANOVA.

### Robustness Check

In order to capture the impact of colocation, during the scam period, on the attractiveness of the two exchanges an analysis of variance was conducted. The results are presented below Table 11.

	<b>variables</b>	Between groups	Within groups	Total	F	Prob>F	Bartlett's test for equal variances:	
	DF	2	199	201			chi2(2)	Prob>chi2
<b>Panal-A</b>	NSE listing variables							
	L <sub>1N</sub>	1977.39	430.56	2407.95	456.96	0.00	104.09	0.00
	L <sub>2N</sub>	760.04	3829.90	4589.94	19.75	0.00	7.70	0.02
	L <sub>3N</sub>	20037.27	10683.10	30720.38	186.62	0.00	93.84	0.00
	L <sub>4N</sub>	309415.15	56425.14	365840.29	545.62	0.00	29.18	0.00
<b>Panal-B</b>	BSE listing variables							
	L <sub>1B</sub>	925.38	2046.52	2971.90	44.99	0.00	53.53	0.00
	L <sub>2B</sub>	44.48	3050.56	3095.04	1.45	0.24	10.68	0.01
	L <sub>3B</sub>	50506.52	36440.49	86947.00	137.91	0.00	50.42	0.00
	L <sub>4B</sub>	308587.87	59474.33	368062.20	516.26	0.00	27.46	0.00

Table 12 portrays all the listing variables of NSE and BSE which are significantly different at 0.01% significance level except New Listing in BSE.

	<b>NSE listing</b>				<b>BSE listing</b>			
<b>Variable</b>	L <sub>1N</sub>	L <sub>2N</sub>	L <sub>3N</sub>	L <sub>4N</sub>	L <sub>1B</sub>	L <sub>2B</sub>	L <sub>3B</sub>	L <sub>4B</sub>
Mean Diff. (scam-pre)	4.95***	3.46***	4.18***	39.11***	1.85***	-0.50	3.80	38.63***
p value	0.00	0.00	0.00	0.00	0.00	0.76	0.25	0.00
Mean Diff. (post-scam)	2.32***	0.85	19.24***	55.85***	3.34***	0.00	32.56***	56.21***
p value	0.00	0.57	0.00	0.00	0.00	0.24	0.00	0.00
Mean Diff. (Post-pre)	7.27***	4.31***	23.42***	94.96***	5.18***	0.08	36.36***	94.84***
p value	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00

Table 13 indicates the post-hoc analysis which is applied after ANOVA was found to be significant for all the listing variables for all the three periods namely, Pre-colocation period (2003-2009), Colo-scam period (2010-2014) and post-co-location period (2015-2019). We applied three post-hoc analysis in order to ensure robustness of the results. Results are found to

be consistent across all the three post-hoc tests. The results in the table present evidence that all other listing variables show a significant difference at all the three periods, apart from post-scam period (p-value = 0.57) for New listing (12n) in NSE. In case of BSE all other listing variables were found to be significantly different across all the three periods apart from post-scam period (p-value = 0.24), and post-pre scam period (p-value = 0.24) for New listing (12b) in BSE.

Thus, we can see that the attractiveness of the exchanges do change during the scam period. However, the finding that the pre and post colocation is impacted because of the scam is quite evident which is consistent with the prior test statistics.

	variables	Between groups	Within groups	Total	F	Prob>F	Bartlett's test for equal variances:	
	DF	2.00	199.00	201			chi2(2)	Prob>chi2
<b>Panel-A</b>	NSE-Trading variables							
	T <sub>1N</sub>	680.52	558.45	1238.97	121.25	0.00	132.31	0.00
	T <sub>2N</sub>	5080.97	2408.59	7489.57	209.90	0.00	41.04	0.00
	T <sub>3N</sub>	9.11	48.84	57.96	18.57	0.00	163.53	0.00
<b>Panel-B</b>	BSE- Trading variables							
	T <sub>1B</sub>	341.75	89.09	430.84	381.69	0.00	157.64	0.00
	T <sub>2B</sub>	33.22	162.43	195.64	20.35	0.00	15.62	0.00
	T <sub>3B</sub>	0.28	10.73	11.01	2.59	<b>0.08</b>	129.50	0.00

Further, we check the differences in the attractiveness in terms of trading variables reports there is significant differences in the attractiveness in terms of trading variables of NSE and BSE at 0.01% significant level for entire period Table 14.

Variable	NSE Trading			BSE Trading		
	T <sub>1N</sub>	T <sub>2N</sub>	T <sub>3N</sub>	T <sub>1B</sub>	T <sub>2B</sub>	T <sub>3B</sub>
Mean Diff. (scam-pre)	-3.86***	5.11***	-0.34***	-2.40***	0.97***	-0.07
p value	0.00	0.00	0.00	0.00	0.00	0.25
Mean Diff. (post-scam)	0.29	7.06***	-0.15	-0.44***	-0.52***	-0.02
p value	0.65	0.00	0.27	0.00	0.01	0.93
Mean Diff. (Post-pre)	-3.57***	12.17***	-0.49***	-2.84***	0.46***	-0.08
p value	0.00	0.00	0.00	0.00	0.01	0.12

Table 14 indicates the post-hoc analysis which is applied after ANOVA was found to be significant for all the trading variables for all the three periods namely, pre-co-location period



(2003-2009), Co-lo-scam period (2010-2014) and post-co-location period (2015-2019). We applied three post-hoc analysis in order to ensure robustness of the results. Results are found to be consistent across all the three post-hoc tests. The results in the table present evidence that all other trading variables show a significant difference at all the three periods, apart from post-scram period ( $p$ -value = 0.65) for turnover ( $t1n$ ) in NSE and Dividend Yield ( $t3n$ ). In case of BSE all other trading variables were found to be significantly different across all the three periods apart from Dividend Yield ( $t3b$ ) for entire three period in BSE. Thus, we can see that the scam period causes significant distinction in the results which is different from the previously conducted  $t$  test. However, the finding that the pre and post colocation is impacted because of the scam is quite evident which is consistent with the prior test statistics.

### Limitations and Future Research

One of the most important aspects of the present study is that it contributes to the extant literature by showing differences in results from that of the previous studies. We found difference in trading where overall trading attractiveness of NSE is reduced. As such, our study is amongst the earliest to ascertain this. For practice this study provides useful insights in terms of decision making and strategy building for a number of stake holders that is policy makers and regulators, stock- exchange investors for trading and firms for listing. This study is useful for regulators to understand the competition between NSE and BSE because, regulator (SEBI) always strives to operate in a fair market environment. The trading attractiveness of NSE has been found to be less than BSE in the post colocation. Policy maker and financial advisors can use this information to make their suggestion accordingly. In terms of trading BSE has picked up accelerated pace in the post colocation, thus reducing its gap from the trading credential of NSE. Similarly, NSE attractiveness in terms of listing has increased in post colocation period. These two findings will provide useful insights to the exchange (NSE & BSE) for understanding their correct stands in the market. The study provides transparency for future research for study in the field of stock market innovation.

The foremost objective of the study was to compare the attractiveness of both the primary stock exchange in India for pre and post colocation. We had considered the innovation of colocation as a landmark technology to compare attractiveness of the Indian stock exchanges. Our result suggests interesting findings for our hypothesized relationships. First, we see that all other hypothesis apart from 3(b) was supported. However, hypothesis: 3(b) was partially supported as the mean value of visibility (L4) was insignificant. This could be because NSE has been more prone to innovation as compared to BSE. This is advantageous and works in the favor of traders than firms that seek to list.

Interestingly, our study differs from most of the literature as a result shows that the listing attractiveness of NSE is increased except for one variable that is for visibility. On the other hand, trading attractiveness is decreased except for one variable that is for price discovery. So, we see that overall “*colocation*” has on average increased the relative listing attractiveness of NSE and decreased the relative trading attractiveness of NSE, respectively.

## Conclusion and Implications

For robustness check, we aimed to consider the period of co-lo-scams, which was revealed only in 2014. So far, we only envisaged a difference between pre-and post-colocation from the point of view of new market innovation. However, there could be an impact of scams in the post-colocation period. This scam revealed many facts about the utility and operationalization of colocation technology. Therefore, we suggest that the period of scams can be neglected. We conduct an Analysis of variance while bifurcating the study into three periods, namely, pre-colocation period (2003-2009), Co-lo-scams period (2010-2013) and post-co-location period (2014-2019). The study results reveal that most variables significantly differ at all three periods for NSE and BSE exchanges. Few variables were found to be sacrosanct across the timelines, irrespective of the scam. These variables were New listing (I2n and I2b) of both the exchanges and turnover (t1n) and dividend yield (t3n) of NSE, and Dividend yield (t3n) of BSE. Both of our studies provide enough evidence that the pre and post colocation periods are different for both the exchanges, be it NSE Colocation (2018) or BSE. Moreover, the study also provides evidence that the difference in the post colocation period from that of the pre colocation period is mainly because of the colocation scam. Therefore, we fulfill the study's objectives by conducting an in-depth analysis of the panel data of all the listed NSE and BSE firms.

## Conclusion

The current study considers only the exchange-specific factors; However, for a better understanding of the factors influencing the overall attractiveness of the exchanges, a cross-country study is also suggested considering country-specific factors. Furthermore, segregated research focusing on the level of development of the countries can provide a better idea of the significant factors influencing the relative attractiveness of exchanges in the developed and emerging economies. We have considered an important innovation of market, the introduction of colocation facility, in India; other innovations like algorithmic trading, high-frequency trading, and the recent introduction of cryptocurrency can be explored in future studies. This study is limited to the stock market, which can be extended to the derivative market for future research.

## REFERENCES

- Abdulraheem, A. (2009). Corruption in India: an overview (Causes consequences and remedial measures). *Social action*, 59(4), 351-63.
- Aggarwal, N., & Thomas, S. (2014). The causal impact of algorithmic trading on market quality. Technical report, IGIDR WP-2014-23.
- Aitken, M.J., Aspris, A., Foley, S., & Harris, FHDB, (2018). Market fairness: The poor country cousin of market efficiency. *Journal of Business Ethics*, 147(1), 5-23.
- Angel, J.J. & McCabe, D. (2013). Fairness in financial markets: The case of high frequency trading. *Journal of Business Ethics*, 112(4), 585-595.
- Brogaard, J., Hagströmer, B., Nordén, L. & Riordan, R. (2015). Trading fast and slow: Colocation and liquidity. *The Review of Financial Studies*, 28(12), 3407-3443.
- Heath, E. (2010). Fairness in financial markets. Finance ethics: Critical issues in theory and practice (Robert W. Kolb Series), 163-178.
- Jawed, M.S. & Chakrabarti, P. (2018). Role of Algorithmic and Co-Location Trading on the Speed of Information Adjustments: Evidence from India. *Emerging Markets Finance and Trade*, 54(9), 2021-2039.

- Krishnamurti, C., Sequeira, J.M., & Fangjian, F. (2003). Stock exchange governance and market quality. *Journal of banking & finance*, 27(9), 1859-1878.
- Noia, C. (2001). Competition and integration among stock exchanges in Europe: network effects, implicit mergers and remote access. *European Financial Management*, 7(1), 39-72.
- Riordan, R., & Storkenmaier, A. (2012). Latency, liquidity, and price discovery. *Journal of Financial Markets*, 15(4), 416-437.
- Sanusi, M.S. (2018). A critical overview of the transparency and competitiveness of the london stock exchange.
- Serifsoy, B. (2007). Stock exchange business models and their operative performance. *Journal of Banking & Finance*, 31(10), 2978-3012.
- Serifsoy, B. (2008). Demutualization, outsider ownership, and stock exchange performance: empirical evidence. *Economics of Governance*, 9(4), 305.
- Shefrin, H., & Statman, M. (1993). Ethics, fairness and efficiency in financial markets. *Financial Analysts Journal*, 49(6), 21-29.