Effect of clearing de-fragmentation on fragmented trading

Working Paper

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Abstract

In many markets, trading occurs across multiple exchanges or trading venues, leading to fragmentation. Central counterparty (CCP) clearing can either mirror this fragmentation or be consolidated through a single CCP or multiple interoperable CCPs. This paper examines the impact of choice of clearing model on trader behaviour under trading fragmentation. The paper shows that when the inter-exchange arbitrage costs are high, informed traders may prefer supplying liquidity on less liquid exchange. However, when such costs are reduced on account of netting after consolidation of clearing, they prefer supplying liquidity on more liquid exchange instead. Using data from implementation of CCP interoperability in India, the paper shows that clearing de-fragmentation improves price informativeness, narrows bid-ask spreads, and improves welfare by reducing adverse selection for uninformed traders.

[1] Any views expressed in the paper are solely of the author and may not represent the views of NSE Clearing.

1 Introduction

Exchanges represent a marketplace for agents with heterogeneous beliefs and motivations to engage and discover price. Therefore, such agents benefit from economies of scale and network externalities if price discovery takes place in a single exchange. Stigler (1964, p. 129) argues that *"The performance of the main function of the exchange as a market-place is subject to economies of scale. The greater the number of transactions in a security concentrated in one exchange, the smaller the discontinuities in trading and the smaller the necessary inventories of securities. As a result the price of a security will almost invariably be 'made' in one exchange."*. Early literature (Pagano, 1989a, 1989b; Chowdhry and Nanda, 1991) also predicts that market participants will prefer the exchange with greater liquidity for better execution prices. This will improve the liquidity on such exchange, causing even more traders to prefer the exchange for execution – setting in motion a positive feedback loop with more and more liquidity being concentrated in one exchange, until it becomes a monopoly market. The early literature acknowledges benefits of potential reduction in explicit costs of trading (such as trading fees) due to competition among multiple exchanges but argues that such potential benefits are far outweighed by the inefficiency in pricing due to liquidity fragmentation (Bloch and Schwartz, 1978).

Notwithstanding these arguments, fragmented trading venues continue to operate in many jurisdictions and continue to thrive despite fragmentation concerns. Regulatory efforts in major jurisdictions have been to increase rather than reduce the number of trading venues. For example, the Regulation-National Market System (RegNMS) in the USA and the Markets in Financial Instruments Directive (MiFID) in the EU sought to allow new entrants with different market models as alternative trading venues (Gomber et al., 2017).

1.1 Fragmented trading and trader preferences

Under trading fragmentation, one market often leads the price discovery process and such discovered price is tracked by other markets (Hasbrouck, 1995). Following literature such as Garbade and Silber (1979), I use the terms "dominant exchange" and "satellite exchanges" to denote such relationship in trading fragmentation. While in certain cases, such as mid-point dark pools (Menkveld et al., 2017), trading venues often formally recognize lit[2] exchanges as sources for price reference; the dominant-satellite relationship exists even without such formal recognition. This empirical fact has been observed in over a long time period and across many

[2] Traditional exchanges, where the limit order book data is made publicly available

asset classes, for instance, equity securities trading on multiple exchanges (Hasbrouck, 1995), common equity index futures contracts listed on multiple exchanges (Roope and Zurbeuegg, 2002), highly fragmented agricultural commodity markets (Xu and Zhang, 2021), internationally important commodities such as crude oil (Shao and Hua, 2022), and even recently developed and semi-regulated crypto markets (Alexander et al., 2022). Traders refrain from trading in other satellite markets if the dominant market is no longer discovering a price. When a circuit breaker is hit in the dominant market, even without the coordination of circuit breakers, the trading activity immediately ceases in other venues (Clapham et al., 2017).

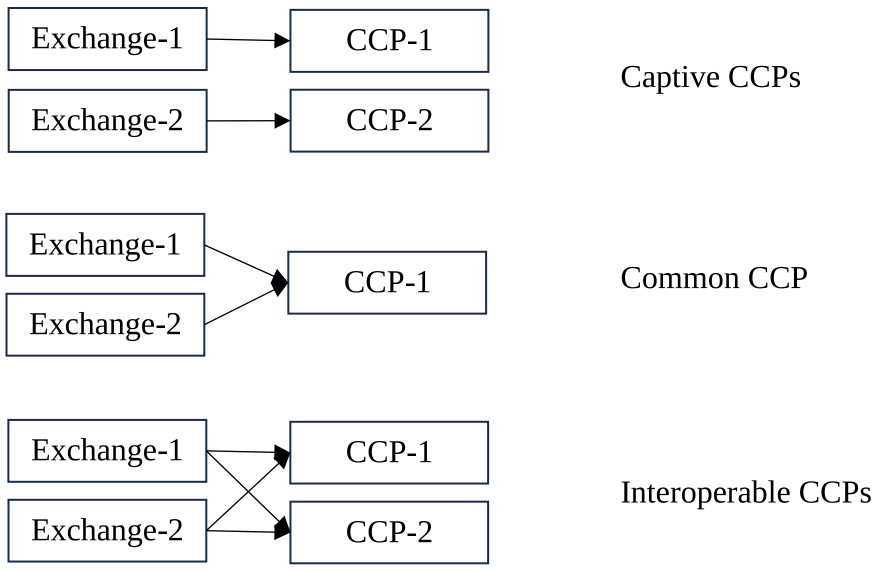
Multiple exchanges have some benefits despite concerns of trading fragmentation. Liquidity provision is ultimately done by market makers or traders submitting passive limit orders to the order book. Therefore, liquidity provision has to take into consideration cost of market access, feeds, connectivity, trading fees etc. (Cespa and Vives, 2022). A monopoly exchange, while improving liquidity due to network externalities, may not have incentive to lower transaction fees in the absence of competition. Rebates for liquidity provision can improve order book depth by redistribution of order flow to the exchange offering rebate (Clapham, 2021). Traders have several heterogeneous preferences, level of sophistication and trading motivations and a single exchange cannot best serve the needs of all traders (Harris, 1993). After considering profit-seeking motives of exchange administrators and heterogeneity of characteristics and preferences among traders, a single exchange may no longer optimal. Trading venues therefore compete on several factors such as access requirements, connectivity, colocation services, tick and lot sizes, order transparency, fees and rebate structures etc. (Gomber et al., 2017). Traders may, therefore, have an inherent preference for the dominant or satellite exchange based on such factors. A secondary benefit of fragmented trading is in terms of overall resilience of the market to operational shocks and outages, flash crashes, and latency arbitrage (Ibikunle and Zhang, 2023).

A number of additional markets were established in the US and EU following RegNMS and MIFID regulations. Following this development, substantial body of literature has studied the effect of introduction of new markets and trader preferences under fragmented trading. Introduction of a new exchange leads to higher price impact on an existing exchange (Guo and Jain, 2023). As market depth reduces with fragmentation, traders concerned with price impact submit orders more aggressively which makes prices in fragmented markets more informative (Chen and Duffie, 2021). Many of the recent additional markets are dark pools or alternative trading venues rather than traditional “lit” exchanges. Dark pools allow for matching of anonymous and unpublished orders outside the lit exchanges. Matching may be at the mid-point of the best bid/ask or other than the midpoint but not beyond the national best bid/ask available at the lit exchanges (Menkveld et al., 2017; Buti, 2017). When a dark pool is introduced alongside a lit exchange, informed traders migrate to the dark pool while uninformed traders remain on the lit exchange (Bayona et al., 2023). Although the fill rates for limit orders increase, the bid-ask spreads widen and executions are at a worse price, leading to decline in welfare of traders (Buti et al., 2017). Therefore, there is a concern that dark pools, which are primarily used by informed institutional traders affect the distribution of welfare between informed large investors and uninformed retail investors. Menkveld et al. (2017) formulate a "Pecking Order Hypothesis" which argues that traders choose venues in order of cost of execution and immediacy, preferring venues with low execution cost and low immediacy first, followed by venues with greater execution cost and greater immediacy. They predict that traders would first prefer midpoint dark pools followed by non-midpoint dark pools followed by lit markets.

1.2 Organization of trading and clearing arrangements

In most major markets, trades done on exchanges are cleared on central counterparty (CCP) clearing houses that guarantee the settlement of trades. Under liquidity fragmentation, with multiple exchanges operating an order book in the same security, there are three possible ways to organize clearing arrangements between exchanges and CC: one-one relationship among multiple exchanges and CCPs "Captive CCPs", many-one relationship with multiple exchanges and a single CCP "Common CCP" and many-many relationships between exchanges and CCPs "Interoperable CCPs". Figure 1 illustrates these models. All the three models are prevalent in practice. For instance, the US cash equities clearing follows a Common CCP model (Awrey and Macey, 2022). Interoperable CCPs exist in Europe (ESRB, 2019), and CCP interoperability was introduced for CCs in India in 2019 (SEBI, 2018). Captive CCPs is a common model, prevalent in markets not having interoperability or common CCs, and particularly common for exchange traded derivatives.

Figure 1: Organization of clearing arrangements



Central clearing primarily achieves cost effectiveness and reduces counterparty exposure due to multilateral netting (Duffie and Zhu, 2011). As a natural extension, the effectiveness of central clearing increases if trades across multiple markets are netted rather than settled separately. Like exchanges, CCPs can also independently benefit from scale and network externalities and are also natural monopolies (Awrey and Macey, 2022). Interoperability among CCPs increases netting benefits and reduces costs for market participants (Cox et al., 2013). In addition to the benefits of netting, interoperability also introduces competition among the interoperable CCPs, which can additionally help drive down cost and improve clearing services (ESRB, 2019). CCP interoperability is not without risks – Awrey and Macey (2022) argue that interoperability can trigger acquisitions and consolidation of interoperable CCPs into a single monopoly CCP, defeating the objective of promoting competition. CCP interoperability can also cause transmission of shocks due to interlinkages between CCPs (ESRB, 2019).

1.3 Literature gap and contribution

While prior literature analyzes trading fragmentation including choice of venue and behavior of traders, such literature does not consider the effect of the choice of clearing model, particularly whether clearing arrangements mirror the fragmentation of trading or not. This paper addresses this crucial gap in literature and makes the following contributions: It constructs a model to show that liquidity supply by informed traders shifts from satellite exchange to dominant exchange upon de-fragmentation of clearing. It also formulates several testable hypotheses based on this model and tests the same based on the data surrounding the implementation of CCP interoperability in India.

I construct a model with two exchanges – a dominant exchange and a satellite exchange (both are traditional "lit" exchanges and not dark pools/alternative venues). The model is used to find out the optimal trading strategy of an informed trader who can attempt to supply liquidity through limit orders at one of the exchanges and get a superior execution price or immediately execute through a market order at the best available price. The model suggests that when arbitrage cost is high, order flow for consuming liquidity in a limit order book is random (buy and sell market orders equally likely and there is sufficient expected order flow on the satellite exchange, an informed trader will find it optimal to supply liquidity on a satellite exchange rather than supplying liquidity on the dominant exchange. This result is consistent with the Pecking Order Hypothesis (POH) of Menkveld et al. (2017) which predicts that traders will prefer low cost and low immediacy venues over high cost and high immediacy venues. The dominant exchange has lower execution cost than satellite exchange when a trader crosses the bid-ask spread to consume liquidity but has greater execution cost when a trader hopes to get a fill on a limit order which supplies liquidity by improving the prevailing best bid or ask. When supplying liquidity, traders prefer the low cost and immediacy venue, i.e. the satellite exchange. However, a change from fragmented clearing to de-fragmented clearing can reduce the cost of arbitrage between dominant and satellite exchange substantially. This increases the cost of execution when supplying liquidity on the satellite exchange by improving the prevailing bid. In such a scenario, the informed trader finds it optimal to supply liquidity on the dominant exchange instead.

Indian cash equities markets comprise of two exchanges with National Stock Exchange of India Ltd. (NSE) being the dominant exchange with about 90% market share during before introduction of interoperability. BSE Ltd is another satellite exchange with the remaining market share[3] (SEBI, 2020). Prior to July 2019, each exchange had a separate captive CCP under a vertically integrated model. NSE Clearing Ltd. (NCL) cleared trades on NSE and Indian Clearing Corporation Ltd. (ICCL) cleared trades on BSE. In July 2019, the clearing model became competitive with the two CCPs entering into an interoperability arrangement.

[3] Although there is a third registered cash equities exchange, its turnover was only 0.0003%, hence not considered.

This allowed traders to choose to clear their trades at any CCP independent of the exchange on which they were executed and also substantially save on costs due to netting and applicable transaction taxes. As a result, the cost of arbitrage trades between the two exchanges reduced substantially. Based on data from Indian markets before and after the implementation of interoperability, I carry out empirical analysis to test multiple hypotheses of the model. The results suggest that de-fragmentation of clearing leads to improvement in market-wide best bid-offer spread and improves the informativeness of prices. The difference between the expected execution price for informed traders and uninformed traders reduces, reducing adverse selection for uninformed traders and improving market welfare. This paper demonstrates the effect of choice of clearing model on liquidity in fragmented markets.

The rest of this paper is organized as follows: The second section develops the model and formulates hypotheses. The third section provides institutional background of market infrastructure in India, data and methodology used for empirical analysis and its results. The fourth section discusses the findings and concludes.

2 Model

I develop a model to analyze the optimal execution strategy of a risk neutral informed trader under liquidity fragmentation and effect of clearing consolidation upon the optimal execution strategy. The informed trader has some private knowledge about a security trading in both a dominant and a satellite exchange. I assume that the informed trader wishes to buy the security. The model can be mirrored for an informed trader wishing to sell the security. The informed trader wishes to minimize the expected execution price. The informed trader also has knowledge of expected order flow from uninformed liquidity traders. The uninformed liquidity trader has a may submit a market order on the dominant or satellite exchange, but the likelihood of order submission on dominant exchange is greater. The liquidity trader equally likely to place buy or sell market order.

The model considers one informed and one uninformed trader, in a three-period model whose broad construction is provided in Figure 2.

Figure 2: The three period model

Initial conditions	Period 1	Period 2	Period 3
Order book of dominant exchange is given exogenously Order book of satellite exchange is determined by arbitrage conditions	The informed trader may submit a buy market order or a buy limit order on the dominant exchange or satellite exchange. If submitting limit order, it improves the current bid available on the exchange.	An uninformed liquidity trader arrives, and based on its preference may submit a market order on main or satellite exchange. This trader is equally likely to submit buy or sell order.	If the informed trader had submitted a limit order in period 1, and the same has not been filled in period 2, then the informed trader cancels such limit order and submits a market order to buy the security.

2.1 Model construction

The prices in the dominant exchange are given exogenously. Let b and a be the best bid and best ask on the main market respectively $(b < a)$. Let $\tau > 0$ represent the tick size, assumed to be common for both exchanges. The dominant exchange has bids and asks available at $b, b - \tau$ and $a, a + \tau$ respectively. Arbitragers ensure that the order book on the satellite exchange within arbitrage bounds from the dominant exchange. Let c represent the cost of arbitrage for executing and settling buy and sell trades in the security across the two exchanges, which includes all relevant factors, including borrowing/inventory costs in case the trades on two markets are settled separately without netting. Therefore, the bids and asks available in the satellite market are $b - c, b - c - \tau$ and $a + c, a + c + \tau$ respectively. An arbitrager will place a limit bid at $b - c$ at the satellite market, because if it is filled, then the arbitrager can immediately execute a sell market order at dominant exchange against the bid b at the main market to make arbitrage profit c. I assume $c \geq 2\tau$. These bids and asks are available in the dominant and satellite exchange before the beginning of period 1.

The uninformed liquidity trader does not have private information about the security and needs immediacy of execution. It always submits market orders and is equally likely to submit buy or sell market orders. The liquidity trader prefers the dominant exchange. The probability of it submitting an order on the dominant exchange is $\lambda > 0.5$ and the same for submission on the satellite exchange is $1 - \lambda < 0.5$. Therefore, the probability of the liquidity trader submitting a buy and sell market order in the dominant exchange is $\frac{\lambda}{2}$ each, and the probability of the liquidity trader submitting a buy or sell market order in the satellite exchange is $\frac{1-\lambda}{2}$ each.

I analyze three different candidate strategies for the informed trader:

1. $Aggressive$ strategy is execution of market order to match the best available offer in period 1.
2. $PassiveDominant$ strategy is improving the bid of dominant exchange in period 1, waiting for a possible execution by matching against incoming market order of liquidity trader in period 2, and if such execution does not occur, executing a market order to match the best available offer in period 3.
3. $PassiveSatellite$ strategy is similar to $PassiveDominant$ strategy, but the informed trader chooses to improve the bid of the satellite exchange rather than the dominant exchange in period 1.

The expected execution price for the liquidity trader under $Aggressive$, $PassiveDominant$, and $PassiveSatellite$ strategies is denoted by $E[P_A], E[P_{PD}]$, and $E[P_{PS}]$ respectively. The informed trader will choose the one that minimizes the expected execution price.

If the informed trader chooses $Aggressive$ strategy, it will submit the market order at the exchange having the better best ask. Since the best asks in main and satellite exchange are a and $a + c$ respectively ($c > 0$), the informed trader will submit the market order at dominant exchange and the execution price will be a. Therefore,

$$E[P_A] = a \tag{1}$$

In $PassiveDominant$ strategy, the informed trader improves the bid at the dominant exchange to $b + \tau$. The probability that the liquidity trader will submit a sell market order at the dominant exchange to match against this improved bid is $\frac{\lambda}{2}$. On the other hand, the probability that the liquidity trader will execute a buy market order on the dominant exchange is also $\frac{\lambda}{2}$, in which case the informed trader will have to execute a buy market order in period 3 against the next best ask, at $a + \tau$. With probability $1 - \lambda$, the liquidity trader will not submit a market order on the dominant exchange, submitting it on the satellite exchange instead. In such a case, the informed trader will still have the best offer at a available on the dominant exchange in period 3.

Thus, the expected execution price is:

$$E[P_{PD}] = \frac{\lambda}{2}(b+\tau) + \frac{\lambda}{2}(a+\tau) + (1-\lambda)a$$

Simplifying, the expected execution price for $PassiveMain$ strategy is:

$$E[P_{PD}] = a + \frac{\lambda}{2}[2\tau - (a-b)] \tag{2}$$

Or

$$E[P_{PD}] = E[P_A] + \frac{\lambda}{2}[2\tau - (a-b)] \tag{3}$$

In $PassiveSatellite$ strategy, the informed trader improves the best bid in the satellite exchange in period 1 to $b - c + \tau$. With probability $\frac{1-\lambda}{2}$, the liquidity trader will submit a sell market order in satellite exchange in period 2 matching with the bid improved by informed trader. With probability $\frac{\lambda}{2}$, the liquidity trader will submit a buy market order on the dominant exchange, consuming the best ask. In this scenario, the informed trader will have to submit a buy market order in period 3 which will match the next best ask at $a + \tau$. With probability $\frac{\lambda}{2}$ and $\frac{1-\lambda}{2}$, the liquidity trader will submit sell market order in dominant exchange and buy market order in satellite exchange respectively, neither matching with the bid improved by the informed trader in satellite exchange nor consuming the best ask in the dominant exchange (total probability $\frac{1}{2}$). In such a scenario, the informed trader will submit a buy market order matching with the best ask of a in the dominant exchange in period 3.

Thus, the expected execution price of $PassiveSatellite$ strategy is:

$$E[P_{PS}] = \frac{1-\lambda}{2}(b-c+\tau) + \frac{\lambda}{2}(a+\tau) + \frac{1}{2}a$$

The above expression can be rearranged as follows to have the first two terms of the specification equal to the expression for $PassiveDominant$ strategy:

$$E[P_{PS}] = a + \frac{\lambda}{2}[2\tau - (a-b)] + \frac{1}{2}[(2\lambda-1)(a-b-\tau) - c(1-\lambda)] \tag{4}$$

So that,

$$E[P_{PS}] = E[P_{PD}] + \frac{1}{2}[(2\lambda - 1)(a - b - \tau) - c(1 - \lambda)] \quad (5)$$

2.2 Optimal strategy for informed traders

The optimal strategy for the informed trader depends on the values of τ, λ and c.

Remark 1: $E[P_{PD}] \leq E[P_A]$

Given the relationship between $E[P_A]$ and $E[P_{PD}]$ in equation (3), $PassiveDominant$ strategy will lead to lower execution strategy as long as $\frac{\lambda}{2}[2\tau - (a - b)] < 0$, in other words, if $a - b > 2\tau$.

The bid-ask spread will always be a multiple of tick size, i.e. $a - b = n\tau, n \in N$.

For $n = 1$, the bid-ask spread is only one tick. In such a case, $PassiveMain$ and $Aggressive$ strategies are indistinguishable, as improving the best bid by one tick equals the ask: a buy limit order improving best bid results in same price as the best ask that a buy market order will match with, therefore $E[P_{PD}] = E[P_A]$.

For $n = 2$, $[2\tau - (a - b)] = 0$, and therefore $E[P_{PD}] = E[P_A] = a$. A risk neutral informed trader will be indifferent between the strategies.

For $n > 2$, $[2\tau - (a - b)] < 0$. Therefore, $E[P_{PD}] < E[P_A]$ i.e., $PassiveDominant$ strategy leads to a lower expected execution price.

Remark 2: $E[P_{PS}] < E[P_{PD}]\ if\ \ c > \frac{(a-b-\tau)(2\lambda-1)}{1-\lambda}$.

Given equation (5) which expresses the relationship between $E[P_{PS}]$ and $E[P_{PD}]$, $E[P_{PS}] < E[P_{PD}]$ if:

$\frac{1}{2}[(2\lambda - 1)(a - b - \tau) - c(1 - \lambda)] < 0$, or

$$c > \frac{(a - b - \tau)(2\lambda - 1)}{1 - \lambda}$$

Remark 3: *All three strategies have the same expected execution price if* $a - b = 2\tau$ *and* $c = \frac{\tau(2\lambda-1)}{1-\lambda}$.

As discussed in preceding discussion, if $a - b = 2\tau$, then $E[P_A] = E[P_{PD}]$. Further, of $c = \frac{(a-b-\tau)(2\lambda-1)}{1-\lambda}$, then $E[P_{PD}] = E[P_{PS}]$.

Substituting $a - b = 2\tau$, i.e. $a - b - \tau = \tau$, $E[P_A] = E[P_{PD}] = E[P_{PS}]$, if $a - b = 2\tau$ and $c = \frac{\tau(2\lambda-1)}{1-\lambda}$.

2.3 Effect of clearing consolidation

If the transactions on the main and satellite exchanges are cleared in separate CCPs, the cost of arbitrage c is likely to be higher; since the arbitrage traders will need to settle funds and securities for arbitrage trades separately on two different CCPs and which could involve funding costs as well as stock borrowing/inventory costs, requirements to maintain margins separately with the two CCPs etc. Technical/operational requirements for dealing with two different CCPs are also likely to be higher. Thus, with greater cost of arbitrage, the informed trader will prefer $PassiveSatellite$ execution strategy.

On consolidation of clearing, the cost of arbitrage c is likely to be substantially reduced due netting of trades, as netting will lead to lower funding/inventory, margins as well as operational costs. With lower c, the $PassiveSatellite$ strategy leads to inferior expected execution price for the informed trader, whose optimal strategy will now be $PassiveDominant$.

There are likely to be a number of observable effects, if the informed trader changes the strategy from $PassiveComplimentary$ to $PassiveDominant$.

I develop the following hypotheses based on the foregoing discussion:

The arbitrage cost between exchanges is likely to be substantial under fragmented clearing. With high cost of arbitrage, informed traders can look to minimize their cost of execution by providing one-sided liquidity in the satellite exchange. However, upon de-fragmentation of clearing, the passive provision of liquidity in the satellite exchange will lead to worse results. This is because given the lower likelihood of getting a fill in the satellite exchange, the potential worsening of price when forced to adopt immediate execution in the dominant exchange erodes the potential benefit of getting a fill at favorable price in the satellite exchange. Accordingly, I state hypothesis H1a as:

H1a: On de-fragmentation of clearing, the trading activity of informed traders on the satellite exchange will reduce.

As the informed traders find it cheaper to execute on the dominant exchange, the overall trading volumes of the dominant exchange as compared to the satellite exchange are also likely to go up. Accordingly, I hypothesize:

H1b: On de-fragmentation of clearing, the trading volume on the dominant exchange will increase.

As informed traders find it remunerative to provide liquidity on the dominant exchange rather than providing liquidity on satellite exchange, the bid-ask spreads on the dominant exchange will become narrower. I hypothesize:

H2: On de-fragmentation of clearing, the market wide bid-ask spreads will narrow.

Liquidity provision on the satellite exchange may be done by arbitrage traders or informed traders. Upon de-fragmentation of clearing, the informed traders do not find it remunerative to provide liquidity in the satellite exchange. Accordingly, the share of arbitrage traders in the liquidity provision on satellite exchange will be likely to increase. Accordingly, I hypothesize:

H3: On de-fragmentation of clearing, the share of arbitrage traders in the trading volumes of the satellite exchange will increase.

Upon de-fragmentation of clearing, the expected execution price of informed traders worsens, and gets closer to the bid-ask midpoint as compared to earlier. The spreads become narrower as well. As a result, the informed traders will not be able to execute orders substantially away from the market price. The average execution price for the informed trader should therefore be closer to the average execution price for uninformed traders. Accordingly, I test the following hypothesis:

H4: On de-fragmentation of clearing, the average execution price for informed traders will be closer to the average execution price for uninformed traders.

3 Empirical analysis

I test the hypotheses developed using the data surrounding the implementation of CCP interoperability from the Indian cash equities market.

3.1 Institutional background

India has a vibrant capital market with 92 million unique client registrations. National stock exchange of India Ltd. is the largest exchange in India. It is the 6th largest exchange in the world in terms of market capitalization. In the cash equities market, it is the 3rd largest in terms of number of transactions, and 8th largest in terms of traded value. It is also ranked 1st in the world in terms of number of contracts traded in derivatives (NSE, 2024).

Indian equities markets comprise of two exchanges: National Stock Exchange of India Ltd. (NSE) and BSE Ltd (BSE). NSE is the dominant exchange with very high market share in terms of turnover, while BSE represents the satellite exchange with the remaining market share. At the time of implementation of CCP interoperability, NSE and BSE of about 90% and 10% respectively (SEBI, 2020). Although significantly smaller than NSE, BSE is also a sizable market, which was ranked 20th in the world in terms of number of transactions in 2019.

Both are multi-asset class exchanges that allow trading of multiple products which include, *inter alia*, cash equities, single stock and equity index derivatives, and FX derivatives. In case of cash equities, companies may choose to be listed on both exchanges or any one exchange[4], and therefore stocks are available for trading on either one or both the exchanges. Companies with larger market capitalization and high liquidity are generally available for trading on both exchanges. To analyze the impact of liquidity on implementation of CCP interoperability, I have considered the top 100 securities in terms of traded value. All these top 100 securities were available for trading on both exchanges.

Before July 2019, the exchanges and CCPs operated in a vertically integrated captive CCP model. Each exchange had promoted a captive subsidiary CCP within the exchange group that exclusively settled the trades for the respective exchange. Therefore, the opposite trades done on the same security on different exchanges could not be netted and had to be settled separately with the respective CCP of the exchange. This meant greater costs for funding liquidity and/or

[4] Except for certain exceptions, like an exchange itself or its group company cannot be listed or traded on the same exchange and must list and trade on rival exchange only.

securities borrowing needs, higher operational/compliance requirements, higher transaction tax requirements and other costs due to segregated settlements.

Securities and Exchange Board of India (SEBI) issued guidelines that required the CCPs to put in place interoperability arrangements (SEBI, 2018). The clearing members of the CCPs could designate any one CCP for clearing of all their transactions on both exchanges. The CCPs implemented interoperability in three asset classes: (i) cash equities, (ii) equity and equity index derivatives, and (iii) FX derivatives. The focus of the empirical work in this paper is on the implementation of interoperability in cash equities due to the rich public disclosures made under the regulatory requirements in cash equities market. Particularly, the client-wise details of large value bulk deals executed in the regular limit order book are publicly disclosed in the cash equities market only. CCP interoperability in the cash equities market was implemented on 15th July 2019[5] (NSE Clearing, 2019).

3.2 Data

I use various publicly available data concerning trades executed on the two exchanges before and after the implementation of CCP interoperability to test the hypotheses developed. The data of one year, from 15th January 2019 till 15th January 2020, i.e. six months before and after the implementation of interoperability is used. The data used is publicly available and was downloaded from each exchange's websites.

I construct two dummy variables $Satellite$ and $PostCIO$ for analyzing the impact of CCP interoperability on various factors. The dummy variable $Satellite$ takes a value 1 for data pertaining to the satellite exchange and takes a value 0 for data pertaining to the dominant exchange. The dummy variable $PostCIO$ takes a value 1 for data for the period after implementation of CCP interoperability, i.e. 15th July 2019 onwards, and takes a value 0 for the period before implementation of CCP interoperability. The interaction term $Satellite \times PostCIO$ is used to measure the effect of implementation of interoperability on the trades done on the satellite exchange.

In India, the term "bulk deals" is used for the refer to the trades done by a single trader wherein the total traded (buy/sell) quantity exceeds the 0.5% of the number of shares listed on the exchange. In India, it is mandatory to assign and specify a unique client code for each individual client at the time of order entry (there are no omnibus accounts). The bulk deals done on an

[5] In the cash equities market, this represents the last date for members to designate their preferred CCP under interoperability.

exchange are publicly disclosed after trading hours, including name of the client, quantity bought/sold and average execution price. Bulk deals are executed in the regular limit order book of the exchange and not in a separate trading window. The clients executing such large deals can be considered as informed traders and their activity on exchanges can be used as a measure of activity of informed traders. Since significant market making activities may be uninformed but can involve buying and selling of large quantities, I aggregate the value of buy and sell trades done by a single client having executed bulk deals and consider the data where the absolute difference in buy and sell value exceeds 100 million Indian Rupees (INR) for a given trade date and client. The variable $BulkDealValue$ represents such value of bulk deals executed in the market.

Exchanges publish security-wise total traded quantity and value each day. The variable $Turnover$ represents the total value of trades (in INR) for a given stock on a given day.

By dividing $Turnover$ by the total traded quantity for the day, the volume weighted average price (VWAP) for a stock for a given day is obtained. Further, the difference in the VWAP between the bulk deals and the VWAP for all trades in the market is calculated. This difference is measured as the variable $ExecDiff$ which represents the absolute difference in the average execution price of informed traders and the entire market, expressed as a percentage of VWAP of the entire market. $BulkShare$ is measured as the share of bulk deals in the overall market turnover by dividing bulk deal value in a security on a day by the total $Turnover$ for the security for the day.

CCPs in India use a high frequency measure of liquidity called $ImpactCost$ in their margin models, to assess liquidity of securities. The impact cost is measured as the percentage change in price from the bid-ask midpoint, that would be caused by execution of a fixed order size. CCPs publish average impact cost of last six months (from the 15^{th} day of every month) based on four random snapshots taken during each trading day for INR 100,000 order size. $ImpactCost$ is considered based on the 6-month average published impact cost corresponding to the 6-month period before implementation of interoperability (15th January 2019 – 15th July 2019) and the 6-month period after implementation of interoperability (15th July 2019 – 15th January 2020). I consider the impact cost data published for NSE's (dominant exchange) order book. The data is considered for all stocks listed on NSE. This data includes the $ImpactCost$ for stocks for securities available for trading on both exchanges as well as those available for trading on NSE alone. I construct a binary variable $CommonSecurity$ which takes value of 1 for securities available for trading on both exchanges and 0 otherwise.

Exchanges in India also publish the data on trader category-wise turnover: proprietary trading desks, different categories of institutional clients, and retail clients. Institutional investors may be informed as well as uninformed (e.g., passive funds). Arbitrage trading between markets will require low latency high frequency trading infrastructure which is typically used by proprietary trading desks. Therefore, I use $PropDeskShare$, i.e. the share of proprietary trading activity among overall market turnover as a measure of share of arbitrage traders in the overall market activity.

Table 1 provides a summary of all variables considered in the analysis.

Table 1: Description of variables

Variable	Description
$Satellite$	Binary variable taking value 0 and 1 for dominant and satellite exchange respectively.
$PostCIO$	Binary variable taking value 0 and 1 before and after implementation of CCP interoperability respectively.
$BulkDealValue$	Value of bulk deals executed in the regular order book where the absolute difference in the total value bought and sold exceeds 100 million INR.
$Turnover$	Total value of trades in a given security on a given day (in INR)
$ExecDiff$	Absolute difference in the volume weighted execution price for bulk deals and the overall market
$ImpactCost$	A high frequency measure of order book liquidity, indicating the difference between average execution price from the mid-price of bid ask spread, expressed as a percentage of the mid-price, for a given order value.
$CommonSecurity$	Binary variable taking value 0 and 1 for securities available for trading exclusively on dominant exchange and securities available for trading on both exchanges respectively.
$PropDeskShare$	Share of proprietary trading desks in total turnover

3.3 Methodology

With $BulkDealValue$ as a measure of informed trading, I estimate the regression model specified in Equation 6 to test the hypothesis $H1a$ by estimating the effect of CCP Interoperability on the bulk deal values on the satellite exchange. $BulkShare$ is included as a control variable. A significant negative coefficient β_3 would indicate that values of bulk deals executed on the satellite exchange have reduced in comparison with the dominant exchange after the implementation of interoperability.

$$BulkDealValue = \alpha + \beta_1 Satellite + \beta_2 PostCIO + \beta_3 Satellite \times PostCIO + \beta_4 BulkShare + \epsilon \quad (6)$$

Equation 7 estimates the effect of interoperability on $turnover$ of the two exchanges before and after CCP interoperability to test *H1b*. This regression model is used to test whether overall turnover at the dominant exchange has increased as compared to the satellite exchange. To capture behavior of highly liquid stocks, day wise turnover of top 100 stocks in terms of turnover is considered. All these stocks are traded in both exchanges. Stock fixed effects are included in the model. Significant negative coefficient β_3 would indicate that turnover of satellite exchange is lower, i.e. turnover of dominant exchange has relatively increased after the introduction of interoperability.

$$Turnover = \alpha + \beta_1 Satellite + \beta_2 PostCIO + \beta_3 Satellite \times PostCIO + StockFE + \epsilon \quad (7)$$

Therefore, to test *H2*, the equation 8 estimates the effect of introduction of CCP interoperability on the liquidity (measured by impact cost) for securities commonly available for trading on both exchanges vs. securities available for trading only on one exchange. The model estimates reduction in the spreads on the dominant market after introduction of interoperability. However, the reduction in spreads should occur only for securities available for trading on both exchanges. In case of securities available for trading only on one exchange, there should not be any difference in the execution strategy on account of CCP interoperability. Lower $ImpactCost$ indicates narrow spreads, therefore negative significant coefficient β_3 would indicate that spreads have narrowed for common securities as compared to non-common securities on introduction of CCP interoperability. Stock fixed effects are included in the model.

$$ImpactCost = \alpha + \beta_1 CommonSecurity + \beta_2 PostCIO + \beta_3 CommonSecurity \times PostCIO + StockFE + \epsilon \quad (8)$$

To test *H3*, i.e. test whether share of proprietary trading desks has gone up in the satellite exchange as compared to the dominant exchange after introduction of CCP interoperability. This is estimated the equation 9, which is structured similar to the earlier regression models.

$$PropDeskShare = \alpha + \beta_1 Satellite + \beta_2 PostCIO + \beta_3 Satellite \times PostCIO + \epsilon \quad (9)$$

To test whether $ExecDiff$, the difference between the expected execution price for informed traders and the overall market has reduced, i.e., to test *H4*, I estimate equation 10. In addition to the effect of interoperability, execution difference can get biased if bulk deal forms a large part of overall volumes and may also differ based on stock specific effects. Therefore, the estimate includes $BulkShare$ as a control variable and also stock specific fixed effects. Negative significant coefficient value of β_1 will indicate the difference to have reduced after the implementation of interoperability.

$$ExecDiff = \alpha + \beta_1 PostCIO + \beta_2 BulkShare + Stock\ FE + \epsilon \tag{10}$$

4 Results

Table 2 provides the estimation of regression model 6. The results suggest that the value of bulk deals on the satellite exchange is higher than the dominant exchange, but while there is no significant change in the bulk deal values after implementation of interoperability, the value of deals on satellite exchange reduces. In other words, the bulk deal volume shifts from the satellite exchange to the dominant exchange. These findings support hypothesis H1a.

Table 2: Impact of CCP Interoperability on value of bulk trades on dominant and satellite exchanges

Dependent Variable: BulkDealValue	
Intercept	838.73* (455.28)
Satellite	1524.75*** (574.98)
PostCIO	77.48 (607.83)
Satellite x PostCIO	-1456.48* (853.89)
BulkShare	1077.28** (487.38)
N	827
Adjusted R-squared	0.01489

Table 3 provides the estimation of regression model specified by equation 7. Tautologically, the turnover on the dominant exchange is higher than the satellite exchange. After the implementation of interoperability, the volume of satellite exchange has reduced significantly. These findings support the hypothesis H1b.

Table 3: Impact of CCP Interoperability on trading activity on dominant and satellite exchanges

Dependent Variable: Turnover	
Intercept	4.797e+09 (6.282e+09)
Satellite	-3.468e+09*** (5.299e+07)
PostCIO	8.052e+08*** (8.329e+07)
Satellite x PostCIO	-7.932e+08*** (7.501e+07)
Stock Fixed Effects	Yes
N	24059
Adjusted R-squared	0.4162

Table 4 provides the estimation of regression model specified by equation 8. The results indicate that $ImpactCost$ of common securities is lower (liquidity is higher), given that most liquid securities are available on both exchanges. The impact cost for such common securities has reduced further after the introduction of interoperability. The results support the hypothesis H2.

Table 4: Impact of CCP Interoperability on liquidity for securities trading on both exchanges

Dependent Variable: ImpactCost	
Intercept	2.553*** (0.4613)
PostCIO	0.6742*** (0.0078)
CommonSecurity	-2.719*** (0.6514)
PostCIO x CommonSecurity	-0.3222*** (0.0082)
Stock Fixed Effects	Yes
N	3028
Adjusted R-squared	0.9452

Table 5 provides the estimation of regression model specified by equation 9. The results suggest that share of arbitrage traders is higher on the satellite exchange and increases further after implementation of interoperability. If the liquidity supply on satellite exchange is supplied by arbitragers deriving prices from the dominant exchange, then the share of arbitrage traders will be higher, which will increase further as the liquidity supply by informed traders shifts to the dominant exchange. Thus, these results support the hypothesis *H3*.

Table 5: Impact of CCP Interoperability on share of activity of arbitrage traders

Dependent Variable: PropDeskShare	
Intercept	22.4629*** (0.8307)
Satellite	2.9571** (1.1748)
PostCIO	0.5121 (1.3776)
Satellite x PostCIO	3.2679* (1.842)
N	24
Adjusted R-squared	0.5806

Table 6 provides the estimation of regression model specified by equation 10. The results suggest that the percentage difference in the execution prices for informed traders and overall market reduces after the implementation of interoperability. This finding supports the hypothesis *H4*.

Table 6: Impact of CCP Interoperability on difference in expected execution prices for bulk deals and entire market

Dependent Variable: ExecDiff	
Intercept	0.3433 (0.9539)
PostCIO	-0.3468*** (0.1299)
BulkShare	-0.4602*** (0.1670)
Stock FE	Yes
N	827
Adjusted R-squared	0.3113

5 Conclusion and discussion

This paper shows that under fragmented trading, if traders seeking liquidity have a preference among dominant and satellite exchanges, and if such order flow is likely to be uninformed and equally likely to be buy or sell, then an informed trader will be better off supplying liquidity on the satellite exchange under high cost of arbitrage and on the dominant exchange under low cost of arbitrage to minimize execution price. Therefore, as the cost of inter-exchange arbitrage reduces dramatically following de-fragmentation of clearing, the informed traders migrate to the dominant exchange.

This argument is supported by the evidence of implementation of CCP interoperability in the cash equities market in India. The analysis shows that after implementation of interoperability, trading activity of informed traders on satellite exchanges reduces and the liquidity provision on satellite exchange is greatly driven by arbitrage desks. The trading volume on dominant exchange increases. As the informativeness of price increases, the market-wide bid-ask spreads become narrower, and the gap between expected execution prices for informed traders and uninformed traders reduces.

The clearing model adopted under fragmented trading, specifically whether clearing mimics the fragmentation of trading on exchanges or is de-fragmented affects behavior of traders. The findings of this paper suggest that in de-fragmentation of clearing can lead to informativeness of market prices and as a consequence improve welfare and reduce adverse selection costs for uninformed traders.

6 References

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