

# **Information and the intermediary: Are market intermediaries informed traders in electronic markets?**

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## **Abstract**

### **Information and the intermediary: Are market intermediaries informed traders in electronic markets?**

Given the lack of any clear evidence on the informational contributions of market intermediaries vis-à-vis their clients in the extant literature, we compare the contribution of intermediaries to price discovery relative to that of outside investors. Further, we analyze whether intermediaries trade ahead of their clients to buttress their profits. Using confidential trades data from the Toronto Stock Exchange, we find that intermediaries account for greater price discovery than other institutional and individual investors, in spite of initiating fewer trades and volume. Our estimates of price discovery attributable to market intermediaries range between 55% and 62%, although these traders are responsible for only 37% of trades, representing 40% of total volume. Our analysis indicates that the informational advantage of intermediaries is greater in stocks with low analyst following (and hence less competition for information). This advantage does not appear to stem from inappropriate handling of customer orders by intermediaries, such as frontrunning or stepping ahead of their clients.

While the role of market intermediaries in equity markets has received significant attention in the literature, little has been done to explicitly compare the informational differences between market intermediaries and their clients. The issue of relative informational advantages of market intermediaries and outside customers is significant from the standpoint of price discovery. Such discovery mainly occurs through the trading of informed traders who trade based on their signals about the asset's unobservable true value. Hence, an understanding of which traders are informed and contribute to price discovery assumes considerable significance.

The literature on the source of information in equities has focused largely on differences between institutions and individuals. Chakravarty (2001) applies the Barclay and Warner (1993) methodology to the question and finds that institutions are responsible for most of the cumulative price impact in his sample. Other studies use the level of institutional ownership to assess the informational advantages of institutions vis-à-vis individuals. While these studies indicate that institutions are more informed than individuals, they are unable to shed light on the informational differences between intermediaries and their clients. Similarly, while some empirical evidence exists that the activities of intermediaries are profitable (Madhavan and Smidt (1993) in the context of the NYSE, and Chae and Wang (2003) in the context of the Taiwan Stock Exchange), there has been no examination of how informed these intermediaries are, and how they compare to other traders in the market. The questions that we seek to answer in this study then are: first, are intermediaries more, or less, informed vis-à-vis their clients? And second, do intermediaries inappropriately use their knowledge of client orders in placing their own orders? We answer these questions in context of a completely electronic, and highly transparent market - the Toronto Stock Exchange.

The question of whether intermediaries possess informational advantages over their clients is prominent in the current debate on the future of the NYSE's floor-based market. Critics of the NYSE

system have focused on the information available to traders and specialists on the floor of the exchange.<sup>1</sup> Hence, it is argued, that creating an electronic system would even out the playing field. Traders on the floor also seem to accept this in their reluctance to change. The underlying assumption here is that the NYSE specialists derive their profits because of the monopoly power conferred to them by the exchange, and not due to any trading expertise. With our study of an electronic market, we test whether the presumption of the irrelevance of intermediaries in a screen based environment is indeed true. We should point out here that our analysis focuses on trading of intermediaries as a group. Thus, specialists and broker-dealers are combined together in our analysis. In the electronic setup of the Toronto Stock Exchange, specialists do not enjoy any informational advantages over other traders and are employed by the same firms that operate as broker-dealers. The structure of the Toronto Stock Exchange bears close resemblance to many European exchanges, such as the Paris Bourse and Euronext. Further, proprietary trading by member firms is important in different market structures. Broker-dealers provide competition to exchanges by frequently internalizing trades. This source of competition is significant even for a floor driven market like the NYSE.<sup>2</sup> It is also likely that such competition will intensify in an electronic environment. In the futures markets, dual traders are similar to broker-dealers in our setup in that they trade for their own account as well as on behalf of their clients. Hence, our definition of intermediaries encompasses this broader group of entities involved in facilitating trading in markets.

Traditional market microstructure literature largely views market intermediaries as uninformed traders who cover their losses to informed traders by charging the adverse selection component of the bid-ask spread. More recent work (Saar (2001)) shows that market intermediaries possess important order flow information which gives them an informational advantage. Madhavan and Smidt (1993) and

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<sup>1</sup> *The Wall Street Journal* (August 2, 2004) quotes Scott DeSano, head of Trading at Fidelity, "...the thing that's so striking is how much information the specialists had versus the rest of the world." ("Big Board Chief's Tough Job: Selling Technology on the Floor")

<sup>2</sup> *The Economist* ("Exchange places," May 3, 2001) comments on the role of investment banks as competition to the NYSE in, "It also says something else about the big investment banks: that they see themselves as the biggest potential rivals to the exchanges. They are, for instance, keen to internalize orders...." In a letter to the editor of the *Wall Street Journal*, Thomas E. Haley, Vice President, Market Data at the NYSE claims that 13% of NYSE volume is internalized by NYSE member firms ("Big Board's 'Woes'? We don't see any," *Wall Street Journal*, October 3, 2003.)

Hasbrouck and Sofianos (1993) find that specialists have an investment motive to their trades. Given the conflicting views of the role of market intermediaries – as passive participants in the traditional microstructure literature, and as active traders taking positions in the market to trade profitably on their information in more recent studies - it becomes an empirical issue to examine whether market intermediaries are informed traders who contribute to price discovery. More importantly, if they are informed, how do they compare to outside customers? In the Holden and Subrahmanyam (1992) framework, informational advantage is short lived. Hence, market intermediaries' ability to predict short-term price movements might be as, or more, valuable than information held by outside customers.

The informational role of intermediaries has received more attention in futures markets, although evidence is mixed. Fishman and Longstaff (1992) find that dual traders (who trade for clients as well their own accounts) in futures markets are informed, while Chakravarty and Li (2003) find that dual traders act as liquidity suppliers. More recently, Kurov and Lasser (2004) find that trades initiated by locals in futures markets are responsible for a majority of the information share in the S&P 500 and Nasdaq 100 futures and E-mini market. This suggests that, in the futures markets, it is the market intermediaries who contribute most to price discovery. However, the combination of two factors – the advantage that market intermediaries draw from their presence on the floor in these markets, and the lower possibility of information asymmetry in futures contracts (as these tend to be on basket securities, or affected by macro-economic factors which are less prone to private information) – makes it difficult to extrapolate any results regarding informational contribution of intermediaries, from futures to equity markets. Kurov and Lasser (2004), in fact, find that the higher information share associated with locals is due to the locals' knowledge of large orders on the floor – information that they use to place orders in the simultaneous electronic market.

Our analysis uses detailed transactions data, with trader classifications, on the 100 most liquid stocks traded on the Toronto Stock Exchange (TSX), for September 2002, and the information shares

methodology developed by Hasbrouck (1995).<sup>3</sup> The TSX is an electronic market, characterized by a high degree of pre-trade transparency, with member firms facilitating trading for their clients (institutional and individual), as well as trading for their own account, and specialists assigned to stocks to maintain a two-sided market. The electronic setup of the exchange precludes informational advantages that market intermediaries enjoy specifically in floor-based markets, from confounding our analysis.

Our results indicate that trades initiated by market intermediaries (for their proprietary accounts) are responsible for a majority of price discovery in our sample. Specifically, the information share associated with market intermediary initiated trades, ranges between 55% and 62% for our sample stocks. This compares to an information share ranging between 38% and 45% for all client initiated trades. This result is even more striking when we consider that intermediary initiated trades form only 37% of all trades, representing 40% of the shares traded. Further, information shares are higher for intermediary initiated trades across different volume stocks (ranging from lower and upper bounds of 50% and 56% for the lowest volume quartile, to lower and upper bounds of 60% and 68% for the highest volume quartile). Intermediary initiated trades also have a statistically higher information share than client initiated trades, after controlling for the respective proportion of trades and proportion of volume. Thus, intermediaries appear to be more informed than all other institutions and individuals combined.

Our study presents compelling evidence that market intermediaries tend to be informed in the conventional sense of contributing to price discovery. Further, by establishing this result in a highly transparent electronic market, we show that this result is not driven by a privileged view of the market on a trading floor. Our results indicate that there is a significant informational role for intermediaries, even in a screen-based environment.

Recent allegations of improper trading by specialists on the NYSE, and the earlier investigations of intermediaries in futures markets, raise the possibility that the higher information share of market intermediaries may be a result of frontrunning, or stepping ahead by brokers. To our knowledge,

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<sup>3</sup> While a longer data period would have been desirable, data constraints limit our sample. However, we show that an analysis of a hold-out sample strongly supports our results from the original sample.

however, previous studies have not addressed the possibility of frontrunning in equity markets. We contribute to the literature by testing for these activities. We find no evidence of such trading by intermediaries on the TSX. We also find that intermediaries have a higher information share (relative to their proportion of trades and volume) in stocks with low analyst following than stocks with high analyst following. This result is consistent with the notion that intermediaries possess a greater comparative advantage in stocks with lower competition for information.

The plan for the rest of the paper is as follows. Section 2 presents the background and motivation of the research. Section 3 describes the institutional features of the Toronto Stock Exchange. Section 4 presents the details of the data used in the paper. Section 5 presents a brief overview of the implementation of the Hasbrouck (1995) information shares methodology in our context. Section 6 presents the results and provides robustness tests. Section 7 discusses the implications of our results, and section 8 concludes.

## **2. Background and Motivation**

The role of information, its sources and how it gets incorporated into prices has received considerable attention in the literature. In our summary of related literature we focus on three streams - price discovery, “informed” traders, and market maker behavior.

Price discovery has recently been studied on many dimensions. Hasbrouck (1995) provides an information shares methodology to measure the contribution of NYSE versus other exchanges to price discovery in the Dow 30 stocks. Huang (2002) and Barclay, Hendershott and McCormick (2003) focus on the ECNs on the Nasdaq market and document that ECNs are the preferred destination for informed traders, accounting for a majority of the information share for Nasdaq stocks. Hasbrouck (2003) studies the index futures markets and finds an overwhelmingly large information share associated with the electronically traded E-Mini contracts. Kurov and Lasser (2004) follow up on Hasbrouck (2003) and attribute this informational dominance of E-minis to trades initiated by locals. Chakravarty, Gulen and Mayhew (2004) find that options play a significant role in price discovery for the underlying stocks.

Anand and Chakravarty (2005) analyze price discovery across trade sizes in options markets and find that small and medium size trades are responsible for a majority of price discovery. While these studies significantly further our understanding of how and where information gets incorporated into prices, the only study focusing on type of traders responsible for discovering prices is Kurov and Lasser (2004). However, their context is very specific to floor-based futures markets. Kurov and Lasser (2004) find that locals use information about large orders on the floor to trade in the simultaneously trading electronic E-Mini market. The analysis of basket securities (index futures) also mitigates private information effects (Subrahmanyam (1991)), and might increase the advantage that market intermediaries enjoy. Thus, these studies do not answer the general question of which traders' trades result in the discovery of prices. We advance this literature by examining the informational contribution of different trader types, specifically market intermediaries versus their clients, in a completely electronic (and highly transparent) environment, and in the context of individual stocks, where the potential for informational effects is known to be stronger than in basket securities. To the best of our knowledge, our study is the first analysis of the informational contributions of intermediaries vis-à-vis other traders within an equity market.

Existing literature, on which trader types are informed in equities, centers on differences between institutional and individual investors. One approach to the issue has been to relate institutional ownership to the level of informed trading in the market (proxied by spreads or various measures of adverse selection). The evidence here generally appears to indicate a positive relationship between institutional ownership and information asymmetry (Kothare and Laux (1995), Heflin and Shaw (2000) Sarin, Shastri and Shastri (2000) and Dennis and Weston (2001)). Chiang and Venkatesh (1988), however, find no relationship between institutional ownership and information asymmetry. Chakravarty (2001) finds that institutional trades, in the TORQ data, account for a majority of the cumulative price impact in his sample stocks. Since member firms' proprietary trades are combined with trades of their institutional clients, and specialist trades are not included in the analysis (these trades, along with certain others, are not identified

in the TORQ data<sup>4</sup>), his analysis focuses on informativeness of individual and institutional trades, rather than on the role of market intermediaries.<sup>5</sup> Thus, while this stream of literature concludes that institutions are more informed than individuals, it does not analyze the role of market intermediaries in price discovery.

The third stream of literature relevant to our study is that on market maker behavior. We note that traditional market microstructure models such as Kyle (1985) and Glosten and Milgrom (1985) divide the trading population into the informed, the uninformed, and market makers. In this framework, market makers lose from trading to informed traders, and the adverse selection component of the spread compensates them for this risk. Some studies have gone beyond this paradigm and also emphasized market makers' informational advantages and expertise. For example, Spiegel and Subrahmanyam (1995) build a model where market makers use their knowledge of future order flow to formulate trading for their own accounts, and equilibrium prices reflect market makers' future expectations about outside investor demands. Madhavan and Panchapagesan (2000) find that the NYSE specialist uses his knowledge of future order flow to set opening prices that are more informative than would result from a simple matching of buy and sell orders. Saar (2001) presents a model where market makers gain useful information about investor endowments through their knowledge of the order flow. Madhavan and Smidt (1993) analyze trades of NYSE specialists on the NYSE and find that specialists possess information about impending order flow.<sup>6</sup> Thus, there is reason to believe that market intermediaries possess important information about the evolution of future order flow and are able to trade as active investors based on this information. Given the short term nature of informational advantages, as in the Holden and Subrahmanyam (1992) framework, it is then not clear who is more informed – intermediaries or their customers.

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<sup>4</sup> In the Koski and Scruggs (1998) TORQ sample, 29% of buy side and 28% of sell side volume does not have any attached identifiers (Table 2, page 62.)

<sup>5</sup> Koski and Scruggs (1998) use TORQ data to analyze trading by securities dealers around ex-dividend days. Their focus, however, is not on information or price discovery.

<sup>6</sup> Chae and Wang (2003) find that market makers on the Taiwan Stock Exchange trade as informed traders rather than liquidity suppliers. In the context of a floor based futures market, Manaster and Mann (1999) find that market makers have an informational advantage over off-exchange traders.

### 3. Institutional details

The Toronto Stock Exchange (TSX) organizes its trading as a pure electronic limit order book, characterized by a high degree of transparency. Participants in the market include member firms, specialists,<sup>7</sup> and outside investors who trade through TSX member firms. Smith, Turnbull and White (2001) illustrate the routing of client orders on the TSX (Figure 1, page 1727). All retail and institutional order flow is routed through a member firm. A member firm can then execute the order within the firm (with the member firm's own account, or another client's account as the counterparty), or send it to the limit order book. The TSX disseminates, in real time, details on orders away from the best bid and ask prices, including broker identifications for the orders submitted. Subscribers also have the option of viewing data aggregated by price, order or submitting broker.

The securities industry in Canada is similar in structure to the US. Broker-dealers fall into three categories: integrated firms, institutional firms and retail firms. Integrated firms are typically affiliates of large domestic banks and operate in both the institutional and the retail markets. These firms tend to be the largest firms in the industry. Institutional firms serve institutional clients. This category includes affiliates of many of the major U.S. and European securities dealers. Firms serving retail clients can be full service firms or discount brokers. As in the US, full service retail firms provide an array of products to the retail investors including financial advice. Discount brokers limit themselves to executing trades at low cost for retail customers. The industry is highly concentrated. For our sample, the 10 largest member firms account for more than 80% of the traded volume.

The Universal Market Integrity Rules (UMIR), established by Market Regulation Services Inc. (the Self Regulatory Organization for Canadian equity markets) govern equity trading in Canada. UMIR

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<sup>7</sup> The assignment of specialists in an electronic market, although unusual, is increasingly being adopted by other such markets (for example, the Paris Bourse, International Securities Exchange and the Stockholm Stock Exchange. Charitou and Panayides (2004) provide a comprehensive review of specialist systems used in various markets.) The specialist, on the TSX, is assigned by the exchange and is responsible for maintaining two sided markets, moderating price volatility, guaranteeing executions for odd lot orders, and for a specified number of shares, also known as Minimum Guaranteed Fill (MGF) orders. Each stock is assigned to a single specialist.

provide clear guidelines giving priority to client orders. Member firms trade for their clients as well as for their own accounts (and for the accounts of their employees) with rules prohibiting frontrunning. Specifically, trading for the firm's account is prohibited if the participant has knowledge of a client order "that on entry could reasonably be expected to affect the market price of a security" (UMIR 4.1-1). Once an order is submitted, client limit orders get priority over principal orders at the same price. Similarly, client market orders gain priority over the member firm's own market orders.

#### **4. Data**

We use proprietary transactions data, on the 100 most liquid stocks, for a 19 day period - September 3 to 27, 2002 from the Toronto Stock Exchange.<sup>8</sup> The data include, apart from time stamped prices and quantities of each trade, the trader type, and the broker associated with the trade on the buy and sell side. The data used in this study identify each counterparty to a trade as a member of one of four trader types – members' trades representing public customers (client orders), members trading for their firm's account (principal orders) or for the private accounts of the firm's employees, and specialist trades.<sup>9</sup> These identifiers are required at the time of order entry. While some of the member firms of the TSX have other lines of business as well, trades on account of these entities are identified as client orders. For example, an order placed for the portfolio management division of a member firm routed through the brokerage division of the same firm would be classified as a client order.<sup>10</sup> This eliminates problems associated with inappropriately assigning trades to intermediaries. We only include trades that occur during regular trading hours (9.30 a.m. – 4.00 p.m.)<sup>11</sup> We also use quotes data to sign trades as buys or

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<sup>8</sup> We use a separate 19 day sample from March 2002 to confirm the validity of our results.

<sup>9</sup> Identifiers also exist for trades by options specialists but such trades are rare and represent 0.33% of all buys and 0.39% of all sells in our data. We ignore these trades in our analysis.

<sup>10</sup> We are grateful to James Twiss, Chief Policy Counsel at Market Regulation Services Inc for clarifying order classifications.

<sup>11</sup> We also filter the data for data errors. Trades with prices or quantities equal to zero are deleted. Trades are also identified as errors if a particular trade is more than four standard deviations away from the average price of the stock for the particular day.

sells. Quotes data include time stamped best bid and ask prices, with the associated quantities, available in the market.

Our analysis focuses on price discovery contributions of market intermediaries versus that of their clients. Hence, in our estimations we use two trader types – clients, and market intermediaries (proprietary and employee trades of brokers, and specialist trades). The Hasbrouck (1995) methodology used in the analysis requires daily estimation of information shares. Accordingly, we include only those days where both trader types trade in the particular stock on the particular day. We also require a minimum of 50 trades in a particular stock in a trading day. Table 1 presents summary statistics for our overall sample, and for quartiles based on the daily average number of trades. We divide the sample into volume quartiles to analyze whether the trading volume of the stock affects price discovery contributions of market intermediaries. For example, on the NYSE, specialist behavior varies by liquidity of stocks (Cao, Choe and Hatheway (1997) document specialists using active stocks to subsidize trading in inactive stocks. Huang and Liu (2003) find support for cross-subsidization by individual specialists on the NYSE.)

Table 1, Panel A shows that out of a possible 1,900 “stock days” (each trading day for each sample stock that is included in the sample, defining the number of days for which estimations are run) in the sample (19 trading days for 100 stocks), 1,870 days meet our selection criteria. While 25 stocks fall in each of the quartiles, the number of stock days varies across the four quartiles. In the highest volume quartile (volume quartile 1) all of the possible 475 stock days (19 trading days each for 25 stocks) are included. The numbers drop as we go down the quartiles to 454 stock days for the lowest volume quartile. Statistics presented are the averages across the number of stock days. Given our selection criterion of the 100 most liquid stocks, we find that, in our sample, an average stock on an average day has 384 trades. However, there is wide variation across the volume quartiles – 129 trades per day for the lowest, to 892 trades daily for the highest volume quartile. The average prices across the four quartiles are similar - volume quartile 2 has the highest average price at C\$32.5, and quartile 3 the lowest at C\$23.4.

## **5. Methodology**

We adapt the information shares technique developed by Hasbrouck (1995) for estimating the contribution of various trader types to price discovery on the Toronto Stock Exchange. Specifically, we divide trades into two categories: those initiated by market intermediaries, and those initiated by their clients. Trades initiated by member firms' for their own proprietary accounts (or their employees' accounts), and those initiated by specialists are classified as market intermediary initiated trades. We are comfortable in combining specialist and member firm initiated trades, because specialists on the TSX have no informational advantages over other traders. Further, these specialists work for the same member firms that act as broker-dealers, ruling out any firm-specific structural differences.<sup>12</sup> We classify a trade as buyer or seller initiated using the Lee-Ready (1991) algorithm. Specifically, trades above the midpoint of the bid and ask prices are classified as buyer initiated, below the midpoint as seller initiated. Trades at the midpoint are classified using the tick test. If the trade occurs on an uptick it is classified as buyer initiated, and as seller initiated if it occurs on a downtick.<sup>13</sup> We then use the buyer and seller types associated with each trade to classify the trade as initiated by one of the two trader types. For example, a buyer initiated trade using the Lee-Ready algorithm, with a specialist or a member firm as the buyer in our data, would be classified as "market intermediary initiated" in our analysis. If more than one trade is reported in the same second for a particular trader type (client or intermediary initiated), we only keep the last trade at the time.<sup>14</sup>

Table 1, Panel B presents the proportion of trades and volume associated with each trader type. The proportions are calculated for each trading day for each stock. The numbers reported are the averages of these stock days. Client initiated trades form the majority of the sample on both dimensions. For the overall sample, clients initiate approximately 63% of trades, and 60% of volume. While client initiated trades form a majority in each of the volume quartiles (both by trading frequency and by volume), the

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<sup>12</sup> Davies (2003) also finds that specialists frequently trade in stocks that are not assigned to them. This supports our decision to combine specialist and member firm initiated trades, as TSX specialists take positions for the proprietary account of the firm.

<sup>13</sup> In matching trades and quotes, we lag the reported quote time by one second instead of the five seconds suggested by Lee and Ready (1991), since TSX is an automated market. Exchange officials suggested the lag and an examination of the data confirms the adjustment.

<sup>14</sup> This is necessary to implement the Hasbrouck (1995) information shares methodology.

proportions are highest for the lowest volume quartile. Approximately 70% of the trades, and 66% of the volume, in the lowest quartile are client initiated. The other 3 quartiles are fairly similar in terms of proportion of trades, but the proportion of volume initiated by clients increases monotonically from quartile 1 (highest volume) to quartile 4 (lowest volume). Market intermediary initiated trades simply represent the rest of our sample, with the highest proportion of volume in the most liquid stocks (47% in volume quartile 1) and the lowest in the least liquid stocks (34% in quartile 4).

Our application of the information shares methodology assumes that prices of the trades initiated by the two trader types, for the same stock, share a common random walk component - also referred to as the efficient price. The information share of transactions initiated by a given trader type is then measured as that group's contribution to the total variance of innovations of this efficient price. Hasbrouck (1995, 2002 and 2003) thoroughly detail the methodology, as well as discuss various associated issues. We provide a brief description in the appendix.

We use actual trade prices to construct the price vector (with a time resolution of one second) used in the estimation. Although different from quotes used in Hasbrouck (1995), this approach is similar to the inclusion of last sale trade prices in the price vector in Hasbrouck (2003), transactions prices in Chakravarty, Gulen and Mayhew (2004), and trade prices of regular and E-mini S&P 500 and Nasdaq 100 futures contracts in Kurov and Lasser (2004). Kurov and Lasser (2004) also use the methodology on prices within a market (rather than across markets), in an application very similar to ours. Our estimations also are subject to the issue faced by Kurov and Lasser (2004), in that trader types are not available to the market in real time. As they discuss, however, the methodology is still appropriate to determine which trader types have a higher information share. For example, we would find that intermediaries have a higher information share if client initiated trades and hence, price moves, tend to error correct to intermediary initiated price moves. We would then be able to say that information is primarily impounded into prices through intermediary initiated trades.

For each stock, we estimate the information share of client initiated, and intermediary initiated trades separately for each trading day (a "stock day" described in section 4). We follow Hasbrouck (1995,

2003) in not including any inter-day price changes. Thus, the analysis yields a set of information share estimates for each stock on each trading day that is included in the sample. We then calculate (and present in the tables) the means of these estimates, for the full sample, or partitioned into volume quartiles (the presentation of averages of estimates from different days follows Hasbrouck (2003)). The number of stock days in the tables provides the number of distinct estimates comprising each aggregation category.

## **6. Results**

### **6.1 Information shares estimates**

We begin our analysis by estimating information shares associated with different trader types for each stock day in our sample. Table 2 presents the average information share for each trader type. We find that market intermediary initiated trades account for a majority of the information share in the overall sample, as well as across volume quartiles. For the overall sample, the information share of market intermediary initiated trades has a lower bound of 55.15% and an upper bound of 61.67%. The lower and upper bounds of information shares of client initiated trades are 38.33% and 44.85%. Across volume quartiles, market intermediary initiated trades have a higher information share for the higher volume quartiles (between 60.31% and 68.40% in the highest volume quartile, and between 58.04% and 64.36% in quartile 2) than in lower quartiles (between 52% and 57.8% in quartile 3, and between 49.95% and 55.8% in the lowest volume quartile). The differences between the midpoints of the upper and lower bounds of intermediary and client initiated trades are significant at the 1% level, using non-parametric z-tests. We follow Booth et. al. (2002), Hendershott and Jones (2005) and Kurov and Lasser (2004) in focusing on midpoints of lower and upper bounds of information shares to compare informational contributions of intermediaries and clients. Huang (2002) compares upper and lower bounds separately. However, to be more conservative we test whether the lower bound of information share of intermediary initiated trades is greater than the upper bound of client initiated trades. We find that for the overall sample, as well as for quartiles 1 and 2, the difference is significant at the 1% level, for quartile 3 at the 5% level, while for the lowest volume quartile the difference is not statistically significant. The results

show that although market intermediaries are responsible for a majority of the price discovery in all volume quartiles, they contribute more in the higher volume stocks. Table 1, Panel B also shows that intermediaries initiate more trades in the more liquid stocks. Thus, the amount of trading and information share appear to be correlated.

## **6.2 Information shares - controlling for proportion of trades and volume**

In this subsection, we follow Barclay and Warner (1993) and Kurov and Lasser (2004) in conditioning information shares on the proportion of trades and volume. Such an analysis is important to rule out the two possible alternatives termed by Barclay and Warner (1993) as the "public information" and the "trading volume" hypotheses. The former hypothesis suggests that if public information is the predominant channel of price discovery and traders trade largely for liquidity reasons, the price series with more trades will pick up more price discovery in the estimations purely because of chance, not because of private information. For example, if about 60% of trades are client initiated and all information is public, then about 60% of price discovery would be attributed to client initiated trades. Similarly, following the intuition laid out in Easley and O'Hara (1987) that relatively larger trades are associated with greater price discovery than smaller trades, the trading volume hypothesis would predict that price discovery associated with a price series is positively related to the fraction of the total trading volume in that price series. For these reasons, it is desirable to control for trading volume to draw reliable conclusions on the contributions of intermediaries to price discovery.

In Table 3, we present the information shares for client and market intermediary initiated trades divided by their respective proportions of trades and volume. These ratios are also calculated on a daily basis, i.e. for each stock on each trading day, and then averaged across stock days for presentation. The intuition here is that if market intermediary initiated trades are more informed, then they will contribute a higher information share after controlling for their proportion of trades and volume in the total sample. We find that this is indeed the case. The ratios of information shares to the proportion of trades and volume are markedly lower for client initiated trades (almost half or less) than market intermediary

initiated trades. Non-parametric z-tests for the equality of medians reject the hypothesis that the midpoints of upper and lower bounds of the ratios are equal in all cases at the 1% level of significance. The difference between the lower bounds of information shares of intermediary initiated trades and upper bounds of information shares of client initiated trades are statistically significant at the 1% level as well for all quartiles. Thus, we find strong support for our earlier result that market intermediaries contribute more to price discovery than their clients. This again suggests that market intermediaries, in aggregate, appear to be more informed than their clients.

### **6.3 Do market intermediaries trade inappropriately?**

A possible reason for observing a higher information share associated with market intermediary initiated trades is trading ahead or “frontrunning” of client orders by market intermediaries. Frontrunning of client orders involves violating priority of client market orders over member firm’s market orders, or the priority of client limit orders over member firm’s own limit orders at the same price. While such activities are prohibited on the TSX, it is possible that intermediaries either trade in violation of the rule, or alternatively, step ahead of client orders. Examples of improper trading by market intermediaries include the investigation of intermediaries in Futures markets (in 1988, the FBI found evidence of wrongdoing by brokers on the CBOT and the CME) for trading ahead of client orders, and the more recent issues arising from the practice of “stepping ahead” by specialists on the NYSE. Intermediaries step ahead of client orders by improving the price over that of a standing limit order. Such behavior is not prohibited by the exchange (making it distinct from frontrunning which is strictly forbidden), and forms the basis of allegations against the NYSE specialist firms. This activity, described as parasitic trading, by Harris (1996) involves buying (selling) ahead of large standing limit orders, thus positioning the parasitic traders to benefit from a potentially favorable price move, while limiting the downside due to the standing order. Parasitic trading might also force the limit order trader to demand immediacy later and buy (sell) from (to) the parasitic trader at a higher (lower) price. In this case, as in the case of frontrunning, we would see initiating trades by intermediaries precede those by their clients.

To analyze this issue, we use the regressions used in Chakravarty and Li (2003) to analyze the relation between client and intermediary initiated trades. These regressions draw on Granger (1980) in testing for econometric causality. Specifically, Chakravarty and Li (2003) regress a market intermediary's (a "dual trader" in their context) customer trades within a time interval on intermediary's proprietary trades, and customer trades in lagged time intervals. The regression equation is of the form:

$$\begin{aligned}
 CustomerNetbuy_t = & b_0 + b_1.CustomerNetbuy_{t-1} + b_2.CustomerNetbuy_{t-2} + b_3.CustomerNetbuy_{t-3} + \\
 & b_4.CustomerNetbuy_{t-4} + b_5.CustomerNetbuy_{t-5} + c_1.IntermediaryNetbuy_{t-1} + c_2.IntermediaryNetbuy_{t-2} + c_3. \\
 & IntermediaryNetbuy_{t-3} + c_4.IntermediaryNetbuy_{t-4} + c_5.IntermediaryNetbuy_{t-5} + v_t
 \end{aligned}
 \tag{1}$$

where  $CustomerNetbuy_t$  is the total number of shares bought minus the shares sold for all client initiated trades through a specific broker in time interval  $t$ . Similarly,  $IntermediaryNetbuy_t$  is the total number of shares bought minus the total shares sold for initiating trades for the intermediaries' own account in time interval  $t$ . The rejection of  $c_1=c_2=\dots=c_5=0$  would suggest that market intermediaries' own trades precede those of their customers. We run these regressions separately for each broker for each stock. To allow for enough trades associated with a particular broker, we restrict our analysis to the top brokers (by volume) in each of the 100 stocks in our sample. Specifically, we estimate the regressions for the top broker alone, the top 5 brokers, and the top 10 brokers in each stock. While the objective here is to cover as much of the sample as possible, we also want to ensure that we do not obscure any behavior that might be exhibited by the biggest brokers only, hence the estimations for the top broker and the top 5 brokers as well.

Table 4, Panel A gives the proportion of volume associated with the three broker cuts. The proportion of volume associated with a broker is calculated as the total number of shares in trades where the broker is involved (on the buy or the sell side) divided by twice traded volume. The average proportion of volume associated with the top broker over our sample stocks is around 25%. This proportion increases to 65% for the top 5 brokers and 85% for the top 10. Thus, our analysis covers a large proportion of total volume in the sample stocks. The choice of the length of the time interval,  $t$ , is

the next decision. The time interval needs to be sufficiently small to capture any frontrunning behavior that might exist, and not so small as to have very few intervals in which any trades occur. Accordingly, we estimate the regressions using 1, 5 and 10 minute aggregations (Chakravarty and Li (2003) use 5 minute intervals in their estimations). The estimations are conducted using generalized method of moments (GMM), and the Wald Chi-squared test is used to test the hypothesis that  $c_1=c_2=\dots=c_5=0$ . Given that there are 100, 500 and 1,000 estimates for the top broker, the top 5 brokers and the top 10 brokers respectively (top 1, 5 and 10 brokers in each of the 100 stocks), we only present the proportion of cases where the null hypothesis is rejected suggesting that intermediaries' own trades precede those of their clients. Table 4, Panel B shows that the null hypothesis is rejected in 7%, or less, of the cases (at the 10% level of significance) with 1 minute intervals, in 11%, or less, of the cases with 5 minute intervals and in only 16%, or less, of the cases even with 10 minute intervals.<sup>15</sup> Given that our tests are based on the premise of short-lived information (Holden and Subrahmanyam (1992)), the results do not support frontrunning, or stepping ahead, of clients' trades by market intermediaries, thus ruling out such improper trading as the source of intermediaries' informational advantage.<sup>16</sup>

#### **6.4: Do intermediaries trade inappropriately – tests using profitable client trades**

Our analysis of frontrunning so far considers all client trades as equally likely to be frontrun. It could reasonably be argued that intermediaries selectively frontrun those client trades that they expect to be informed. While it is difficult to come up with ex-ante measures of probability of a particular trade being informed, we would expect informed trades to be ex-post profitable. We utilize this intuition to proxy informed client trades by ex-post profitability. The profitability of a trade is calculated as the

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<sup>15</sup> We also ran the regressions with an aggregation interval of 30 seconds. The rejection rate drops to about 5% for all the broker cuts.

<sup>16</sup> Chakravarty and Li (2003) also test for “piggybacking” by intermediaries in futures markets. Such follow on trading would not give us the higher information share that we see associated with intermediaries' trades in our analysis, and hence is not our focus here. However, we run those regressions and find no evidence of piggybacking by intermediaries on the TSX. Results are available from the authors.

difference between the midpoint of the closing bid and ask prices of the stock on the day the trade occurs, and the trade price for buy orders, and the difference between the trade price and the closing bid-ask midpoint for sell orders. We then present the proportion of profitable client trades for which there is a firm trade (for the account of the intermediary the client order is routed through) in the same direction in a specified period before the client trade. We use one, five and ten minute intervals to conduct the analysis. We calculate this proportion of client trades that are frontrun for the top 25%, top 10% and top 5% of profitable client trades. As a benchmark, we use the opposite end of the tail - the top 25%, top 10% and top 5% loss-making trades. If intermediaries selectively frontrun profitable client trades, we would expect the proportion of profitable trades frontrun to be higher than the proportion of loss-making trades frontrun. Table 5 presents the results. We find that the proportion of trades frontrun is very low, with the highest proportion (6.02%) for the top 5% of profitable trades for the ten minute interval. However, we cannot attribute this to any systematic frontrunning as the proportion of loss-making trades that are frontrun by intermediaries is slightly higher. For shorter (and more likely) frontrunning intervals, the proportion of client trades frontrun is substantially smaller. For instance, proprietary trades occur in the one minute before the top 5% of profitable client trades only 1.38% of the time. Here again, even these cases seem to be a result of random chance as seen by the proportion of loss-making trades frontrun (1.67%). Hence, we do not find any evidence that intermediaries single out profitable trades and trade ahead of them.

### **6.5: Does client volume drive intermediary information share?**

In the previous sections we find that intermediaries do not appear to trade inappropriately on the TSX. However, one of the sources of information for these intermediaries is the order flow of their clients. In this section, we examine whether this source of information is the predominant driver of our finding that market intermediaries have higher information share than their clients. To analyze this, we first calculate the proportion of client and intermediary initiated trades for each broker for each stock in our sample. Based on this proportion, we classify a particular intermediary in a particular stock as one

with “high-client-volume” if the proportion of client initiated volume is greater than 50% of all volume associated with the intermediary. “Low-client-volume” intermediaries in a particular stock are those which have a majority of their initiated volume for the firm’s own account. We then create three price series: all client initiated trades, intermediary initiated trades of high-client-volume brokers, and intermediary initiated trades of low-client-volume brokers. Table 6, Panel A presents the proportion of trades and volume associated with the three price categories. Client initiated trades remain the highest proportion of trades and volume in the sample. However, a significantly higher proportion of firm initiated trades are associated with low-client-volume intermediaries than with high-client-volume intermediaries. To verify that this is a result of our classification criterion and not because low-client-volume brokers handle more volume (that is, it could be that low-client-volume intermediaries trade more for their own accounts, but are also associated with a majority of the overall client volume), we break down client initiated volume associated with the two broker classes in Table 6, Panel B. For the overall sample, approximately 56% (42.6% for clients and 13.8% for their own accounts) of all volume is associated with high-client-volume intermediaries. Across volume quartiles, except in the highest volume quartile, high-client-volume intermediaries account for the majority of volume. Thus, we rule out the possibility that our classification assigns overwhelmingly dominant intermediaries to the low-client-volume category.

Table 6, Panel C presents the information shares associated with the three price categories. If intermediaries derive their information primarily from client order flow then we should expect intermediary initiated trades of high-client-volume brokers to have a higher information share than intermediary initiated trades of low-client-volume brokers. We find the opposite. The information share of low-client-volume intermediary initiated trades is significantly higher. For the overall sample, proprietary trades of low-client-volume intermediaries have a lower bound of information shares of 41.1% and an upper bound of 47.7%. This compares to lower and upper bounds of information shares of

proprietary trades of high-client-volume intermediaries of 14.8% and 18.2%.<sup>17</sup> We also find that the difference between low and high-client-volume intermediaries is higher for the higher volume quartiles.<sup>18</sup> Realizing that proprietary trades of low-client-volume intermediaries form a higher proportion of trades and volume than proprietary trades of high-client-volume intermediaries, we control for their respective proportion of trades and volume in an analysis similar to that presented in Table 3. Results show that low-client-volume proprietary trades have a significantly higher (at the 1% level) information share after controlling for their proportion of trades and volume in the overall sample, and in all volume quartiles, except the lowest volume quartile (quartile 4).<sup>19</sup>

Our findings thus do not support client order flow being the primary source of information for intermediaries. In fact, our results indicate that the intermediaries associated with the highest information share trade primarily for their own accounts.

#### **6.6. Does the competition for information affect intermediary informational advantage?**

In this section we analyze whether intermediary information share is affected by the competition for information in the stock. We expect this competition to be higher in stocks with more analyst coverage (Brennan and Subrahmanyam (1995)). Accordingly, we divide our sample into two halves based on the number of analyst estimates for the stock in the IBES data in September 2002. The IBES database contains information on 94 of the 100 stocks in the sample. In table 7 we present the ratios of information shares to the proportion of trades and the proportion of volume for these 94 stocks only.<sup>20</sup> The ratios are presented separately for stocks with high and low analyst coverage. We find that the midpoints of lower and upper bounds for both the ratios are significantly higher (at the 1% level using the non-parametric z-

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<sup>17</sup> Similar to our earlier analysis, the combined information share of intermediary initiated trades is significantly higher than those of client initiated trades.

<sup>18</sup> The differences are statistically significant at the 1% level across all volume quartiles between the midpoints of the information shares, as well as between the lower bounds of information shares of low-client-volume intermediaries and the upper bounds of information shares of high client volume intermediaries.

<sup>19</sup> Detailed results are available from the authors.

<sup>20</sup> We also conducted the analysis assuming that the six missing stocks have low analyst coverage, with similar results.

test) for intermediary initiated trades for stocks with low analyst coverage than those with high analyst coverage. There is no corresponding difference in either of the two ratios for client initiated trades. We further confirm the relationship between the informational contribution of intermediary initiated trades and analyst coverage by regressing the midpoints of the upper and lower bounds of ratios of information shares to proportion of trades and volume, on the number of analysts. The coefficient for the number of analysts in the regression with ratio of information shares to proportion of trades as the dependent variable is  $-0.014$  (t-statistic of  $-2.62$ , significant at the 1% level). The coefficient, when we use the ratio of information shares to proportion of volume, as the dependent variable is  $-0.036$  (t-statistic of  $-3.10$ , significant at the 1% level). Neither regression yields statistically significant coefficients for client initiated trades. Our results thus indicate that, although intermediaries are responsible for higher price discovery in all stocks, their comparative advantage is significantly higher in stocks where the competition for information is lower.

## **6.7 Robustness**

### **6.7.1 Information shares-different sample period**

To analyze whether our information share results are sample specific, we estimate information shares of client and intermediary initiated trades for a hold-out sample comprising 19 days in the month of March 2002 (March 1, 2002 – March 27, 2002).<sup>21</sup> We apply the same sample selection criteria to this period as well. We analyze the 100 most liquid stocks, and for a stock day to be included, require trades by each trader type during the day, and at least 50 trades during the day for the stock. This leaves us with 1,850 stock days (out of a possible 1,900), with 474 in the most liquid quartile to 450 in the least liquid. Table 8, Panel A presents the summary characteristics. This sample is similar to our September 2002 sample, with around 430 trades for an average stock day, ranging from approximately 929 in the most liquid quartile to 174 in the least liquid. Table 8, Panel B also shows that, similar to our earlier sample,

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<sup>21</sup> The March trades data is similar to the September data in its detail, with the exception that it doesn't contain identifiers for submitting brokers. Fortunately, this does not affect our information shares analysis.

most of the trades and volume tends to be initiated by clients. Clients initiate more than 70% of trades and 63% of volume in the overall sample. In a trend we saw in Table 1, client initiated trades and volume are higher for the lower volume quartiles.

Table 8, Panel C presents the information share contributions of trades initiated by the two trader types. For the overall sample, the lower and upper bounds, for the information share of client initiated trades, are 36.55% and 42.86%, and that of market intermediary initiated trades are 57.14% and 63.45%. While the information share of intermediary initiated trades is lower for the lower volume quartiles, it is still higher than that of client initiated trades. Thus, in the lowest volume quartile, market intermediary initiated trades make up only 29% of volume but contribute between 55% and 60% of the information share. Although for brevity we do not present the ratios of information shares to the proportion of trades and volume, the ratios are significantly higher (at the 1% level of significance using the non-parametric linear rank sum z-statistic) for intermediary initiated trades compared to client initiated trades. We also confirm our results by comparing the lower bounds of information shares (and ratios) of intermediary initiated trades with the upper bounds of information shares (and ratios) of client initiated trades. The differences are significant at the 1% level. We thus find support for our earlier result that intermediaries provide a majority of the price discovery on the TSX.

### **6.7.2 Information shares – using quotes**

We now turn to the possibility of common information, available to intermediaries as well as their clients, confounding our results. While client initiated trades form a substantial majority of the sample, hence reducing the likelihood that market intermediary initiated trades are picking up a larger proportion of public information in the market, we specifically examine the price discovery contributions of client and intermediary initiated trades *over and above* that of bid-ask quotes. We assume that any public information will be included in quote changes. Hence, any information share that we attribute to client and intermediary initiated trades after including the quotes in our estimation will reflect the private information behind those trades. This is especially true of the lower bound of information shares as this

estimate reflects the incremental contribution of the price series that is uncorrelated with the other price series in the estimation. To conduct this analysis we use three price series: client initiated trades, intermediary initiated trades and midpoint of the bid and ask quotes.<sup>22</sup> Table 9, Panel A contains the information shares for the September 2002 sample. The lower and upper bounds of information shares of client initiated trades are 9.97% and 11.97%, while those for intermediary initiated trades are 17.09% and 19.25%. Intermediary initiated trades have higher information shares in all volume quartiles, although the differences are greater for the higher volume quartiles. The comparison of lower bound of information shares of intermediary initiated trades with the upper bound of information shares of client initiated trades yields similar results. The difference is significant at the 1% level for the overall sample and quartiles 1 and 2 and at the 5% level for quartiles 3. The lowest volume quartile does not show significant differences. Recall from Table 1 that intermediary initiated trades form a smaller proportion of trades and volume than client initiated trades. The differences between information shares of intermediary and client initiated trades are significantly different (at the 1% level) after controlling for their proportion of trades and volume.<sup>23</sup>

Table 9, Panel B presents the results of a similar analysis for the March sample. The results are very similar to those discussed above. For the overall sample, intermediary initiated trades account for between 16.34% and 18.37% of information share, compared to between 9.48% and 11.47% for client initiated trades (significantly higher at the 1% level). Thus, our results in Table 9 confirm our earlier finding that market intermediary initiated trades contribute more to price discovery than client initiated trades.

### **6.7.3 Cross-listed stocks**

In this section, we examine the possibility of cross-listing in the US affecting our results. To analyze if there is any difference in information shares of stocks which are traded primarily in an

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<sup>22</sup> Quotes are lagged 1 second in matching with trades. The results with no lag are similar and lead to the same conclusions.

<sup>23</sup> Results are not presented here for brevity but are available from the authors.

exchange in the US, and those that are traded primarily on the TSX, we calculate the market share of TSX for our sample stocks. The market share is based on the volume traded in the TSX and the relevant US exchange during our sample period (September 2002). Trading data from the TAQ database is used to calculate volume traded on the US exchange. We then summarize information shares separately for those stocks with 50% or more of their trading volume on the TSX (this includes the 30 stocks that are not listed in the US and hence have 100% of volume on the TSX) and those with less than 50% of volume on the TSX.<sup>24</sup> Table 10 presents the results. We do not find any evidence to suggest that cross-listing drives our result of higher information shares attributable to market intermediaries. Market intermediary initiated trades contribute significantly more to price discovery than client initiated trades regardless of the market share of TSX for the sample stocks.<sup>25</sup>

#### **6.7.4 Internalized trades**

Smith, Turnbull and White (2001) find that intermediaries effectively screen out informed trades in the upstairs market. Thus, trades in the upstairs market tend to be uninformed, and are internalized by the member firm, with the firm crossing the trade – either as principal, or with another client’s order (page 1727, Smith, Turnbull and White (2001)). For our analysis, this raises the possibility that the information share of our sample of client initiated trades is biased downward due to the mixing up of these clearly uninformed trades with other client initiated trades. Although this does not change the conclusion that intermediaries are more informed in aggregate, since they contribute most to price discovery, it could affect the results for the ratios of information shares to proportion of trades and volume. To analyze this issue, we divide all

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<sup>24</sup> Our decision to divide the sample by market share is consistent with Eun and Sabherwal (2003), who find that, for Canadian stocks, price discovery in a market (TSX or the US exchange) is directly related to the share of volume traded in the market. Thus, our analysis serves as an adequate control of whether trading in the US affects our conclusions about the dominance of intermediaries in price discovery.

<sup>25</sup> The information share of intermediaries is significantly higher for the 30 stocks listed only the TSX when calculated separately as well. Also, the lower bound of information shares of intermediary initiated trades is statistically higher than the upper bound of client initiated trades for all categories except in the lowest volume category.

trades for the September sample into three categories- client initiated, non-internalized trades; intermediary initiated, non-internalized trades; and all internalized trades (client or intermediary initiated). A trade is classified as internalized if the same member firm is on the buy as well as the sell side. We find that for the overall sample, internalized trades represent 13.87% of all trades but 39.46% of the total volume.<sup>26</sup> As expected, internalized trades contribute less to price discovery than other categories. Specifically, the information share for internalized trades ranges between 9.67% and 14.72%, whereas intermediary initiated trades have lower and upper bounds of 46.94% and 54.65%, and client initiated trades of 33.13% and 41.34%. We also find that the ratios of information shares to the proportion of trades as well as volume are still significantly higher (at the 1% level) for intermediary initiated trades than client initiated trades. Thus, our results are not affected by trading in the upstairs market.<sup>27</sup>

## **7. Discussion of results**

We provide evidence that intermediaries contribute more to price discovery than other traders on the TSX. This contribution is disproportionately higher than their trading in the market and is not driven by frontrunning of clients. Further, in our examination of the causes of this informational advantage we do not find that a simple specification based on the client volume handled by the intermediary explains our results. The finding of client volume not being correlated with the intermediary information share is consistent with the anecdotal evidence from futures markets that some "dual traders" in these markets use client volume to mask their own trading activity. A similar situation could exist for brokers on the TSX where other traders can see which broker has submitted a particular order but not if the order is for the

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<sup>26</sup> In the Smith, Turnbull and White (2001) sample, upstairs trades account for 55% of the volume. However, they note that these trades are more common in illiquid securities. Thus, our sample selection criterion of picking the 100 most liquid firms on the TSX might account for the difference.

<sup>27</sup> Results for the volume quartiles are similar, and are available from the authors.

proprietary account or client account. This provides additional camouflage for intermediaries' informed trades.

We do not rule out the possibility that there are more complex factors which correlate better with intermediary information share. However, these might be difficult to identify empirically. Thus, while we can see that intermediaries are skilled in their trading, we do not isolate what the particular skill is. This situation, albeit new in this context, is not new in the literature. Even with traders conventionally thought of as informed (e.g., institutions) there needs to be more understanding of exactly what the information is, aside from the argument that such agents are probably more skilled at analyzing fundamentals and assessing the direction of future price moves. Our results need to be seen in a similar vein, that intermediaries are skilled short-term traders and given the short-term nature of certain informational advantages, are responsible for a majority of price discovery.<sup>28</sup> Further, we find support for the argument that their skills give them a greater comparative advantage in stocks with less competition for information. This result, combined with results from previous literature, indicates a competitive market for information with intermediaries, analysts and institutions as the main players. We should note here that previous studies have combined client and firm trades as institutional trades in their analysis. Hence, our results should be seen as complementary to previous research in determining which of these are more informed. Our research, however, establishes that intermediaries need to be considered separately as informed traders in theoretical as well as empirical research.

## **8. Conclusion**

Given the lack of any clear evidence on the informational contributions of market intermediaries vis-à-vis their clients, we analyze whether market intermediaries are informed traders, and whether they trade ahead of their clients to buttress their profits.

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<sup>28</sup> Although we conjecture that intermediaries have a short-term view of the market, we cannot rule out the possibility that they possess information relevant over the long-term as well.

Using confidential trades data from an electronic equity market, we find that intermediaries contribute more to price discovery than their clients. Specifically, our results show that intermediaries' share of price discovery ranges between 55% and 62%, while their share of initiated volume is around 40%. Adjusted for the proportion of trades and volume, intermediaries' information share is significantly higher than that of their clients. This indicates a dominant informational role for intermediaries on the Toronto Stock Exchange – an electronic equities market. Further, we find that this result is not driven by illegal or improper trading behavior, such as frontrunning or stepping ahead of client orders. We find that our results are not associated with the volume of client order flow handled by an intermediary. Also, our results extend to a different sample period, and across cross-listed stocks. We also test for the possibility of public information confounding our results and find that not to be the case.

Our results have implications for the debate between proponents of the floor and the screen based systems. Both sides seem to believe that such a transition would make intermediaries irrelevant from an informational viewpoint. We show that this is not the case. Our evidence indicates that intermediaries contribute more to price discovery, and hence tend to be more informed, even in a transparent electronic market.

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**Table 1 : Summary Statistics**

This table summarizes the sample used in the study. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. The numbers are first calculated for each stock each day and then averaged for presentation here. Statistics are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock. Panel A presents characteristics of stocks included in the sample, and Panel B presents the proportion of trades and volume initiated by the two trader types.

**Panel A: Characteristics of stocks in the sample**

Quartiles	Number of underlying stocks	Number of stock days estimated	Average daily number of trades	Average Price	Average trade size	Average daily share volume
<b>Overall</b>	100	1870	384.2	27.0	1,594.4	728,761.9
<b>(Highest) 1</b>	25	475	892.1	27.9	1,896.9	1,940,420.0
<b>2</b>	25	475	304.1	32.5	1,132.9	353,627.0
<b>3</b>	25	466	196.4	23.4	1,801.6	380,588.2
<b>(Lowest) 4</b>	25	454	129.4	23.8	1,548.1	210,921.0

**Panel B: Proportion of trades and volume by trader type**

Quartiles	Number of underlying stocks	Number of stock days estimated	Client initiated		Market intermediary initiated	
			Proportion of trades	Proportion of volume	Proportion of trades	Proportion of volume
<b>Overall</b>	100	1870	62.56%	59.81%	37.44%	40.19%
<b>(Highest) 1</b>	25	475	60.09%	53.36%	39.91%	46.64%
<b>2</b>	25	475	59.66%	58.52%	40.34%	41.48%
<b>3</b>	25	466	61.18%	61.84%	38.82%	38.16%
<b>(Lowest) 4</b>	25	454	69.60%	65.81%	30.40%	34.19%

**Table 2: Information shares by trader type**

This table summarizes the results of Hasbrouck (1995) information share estimations. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. Information shares are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock.

Quartiles	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated	
			Min	Max	Min	Max
<b>Overall</b>	100	1870	38.33%	44.85%	55.15%	61.67% <sup>a</sup>
<b>(Highest) 1</b>	25	475	31.60%	39.69%	60.31%	68.40% <sup>a</sup>
<b>2</b>	25	475	35.64%	41.96%	58.04%	64.36% <sup>a</sup>
<b>3</b>	25	466	42.20%	48.00%	52.00%	57.80% <sup>a</sup>
<b>(Lowest) 4</b>	25	454	44.20%	50.05%	49.95%	55.80% <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint of upper and lower bounds of client and intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

**Table 3: Information shares-controlling for proportion of trades and volume**

This table summarizes the results of Hasbrouck (1995) information share estimates divided by the proportion of trades and volume. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. The ratios are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock.

Quartiles	Number of stocks	Number of stock days estimated	Information share/Proportion of trades				Information share/Proportion of volume			
			Client initiated		Market Intermediary initiated		Client initiated		Market Intermediary initiated	
			Min	Max	Min	Max	Min	Max	Min	Max
<b>Overall</b>	100	1870	0.62	0.74	1.79	1.98 <sup>a</sup>	0.72	0.85	1.94	2.14 <sup>a</sup>
<b>(Highest) 1</b>	25	475	0.53	0.68	1.60	1.82 <sup>a</sup>	0.62	0.78	1.42	1.61 <sup>a</sup>
<b>2</b>	25	475	0.61	0.72	1.59	1.76 <sup>a</sup>	0.67	0.79	1.78	1.96 <sup>a</sup>
<b>3</b>	25	466	0.70	0.80	1.88	2.05 <sup>a</sup>	0.82	0.95	2.06	2.25 <sup>a</sup>
<b>(Lowest) 4</b>	25	454	0.66	0.75	2.09	2.31 <sup>a</sup>	0.77	0.88	2.52	2.75 <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint (of upper and lower bounds) of the ratios for client and intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

**Table 4: Test of intermediary trades preceding client trades**

The table presents results of tests of the hypothesis of frontrunning or stepping ahead of client orders by intermediaries. Panel A presents the proportion of sample represented in the tests for top broker alone, the top 5 brokers and the top 10 brokers. Panel B presents the proportion of cases where the null of  $c_1=c_2=\dots=c_5=0$  is rejected in equation 1, at the 10% level of significance. A rejection implies frontrunning of client orders by intermediaries. Equation 1 is estimated using trades data for the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. The regressions are estimated separately for each broker, using GMM. The null hypothesis is tested using the Wald Chi-square test statistic. Results are presented for the top broker alone, for the top 5 brokers and the top 10 brokers.

**Panel A: Proportion of initiated volume in which the top broker, the top 5, and top 10 brokers are involved**

	Proportion of Volume		
	Mean	Min	Max
<b>Top Broker</b>	25.0%	10.1%	67.2%
<b>Top 5 Brokers</b>	64.6%	44.4%	95.5%
<b>Top 10 Brokers</b>	85.1%	68.6%	98.1%

**Panel B: Proportion of cases where the null of no front-running is rejected**

	Aggregation interval (in minutes)	Proportion of cases rejected
<b>Top Broker</b>	1	7.0%
<b>Top Broker</b>	5	10.0%
<b>Top Broker</b>	10	16.0%
<b>Top 5 Brokers</b>	1	6.2%
<b>Top 5 Brokers</b>	5	11.0%
<b>Top 5 Brokers</b>	10	15.2%
<b>Top 10 Brokers</b>	1	6.5%
<b>Top 10 Brokers</b>	5	11.1%
<b>Top 10 Brokers</b>	10	15.8%

**Table 5: Test of frontrunning and stepping ahead-profitable trades analysis**

The table presents the results of frontrunning of profitable client trades by the intermediaries those trades are routed through. We use transactions data for the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. The profitability of a trade is calculated as the difference between the midpoint of the closing bid and ask prices of the stock on the day the trade occurs, and the trade price for buy orders, and the difference between the trade price and the closing bid-ask midpoint for sell orders. The table presents the proportion of profitable client trades for which there is a firm trade (for the account of the intermediary the client order is routed through) in the same direction in a specified period before the client trade. We use one, five and ten minute intervals to conduct the analysis. We calculate this proportion of client trades that are frontrun for the top 25%, top 10% and top 5% of profitable client trades. As a benchmark, we present the numbers for the opposite end of the tail - the top 25%, top 10% and top 5% loss-making trades.

<b>Proportion of cases where firm (proprietary) trade in the same direction</b>				
<b>Percentile</b>	<b>Frontrunning interval (in minutes)</b>		<b>Profitable trades</b>	<b>Loss-making trades</b>
25%	1		0.41%	0.46%
25%	5		1.39%	1.62%
25%	10		2.51%	2.83%
10%	1		0.80%	0.91%
10%	5		2.39%	2.74%
10%	10		4.11%	4.64%
5%	1		1.38%	1.67%
5%	5		3.62%	4.32%
5%	10		6.02%	7.08%

**Table 6: Analysis of the effect of proportion of client volume on intermediary information share**

This table presents the information shares of intermediary initiated trades separately for proprietary trades of intermediaries depending on their relative volume of client trading. Intermediaries are classified as “high-client-volume” if 50% or more of the volume initiated by these intermediaries is on behalf of their clients. Those with less than 50% of their volume associated with clients are classified as “low-client-volume” intermediaries. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. Panel A summarizes the proportion of trades and volume associated with the three price series: client initiated trades, high-client-volume intermediary initiated trades and low-client-volume intermediary initiated trades. Panel B presents the proportion of trading initiated by clients and intermediaries broken down by high and low-client-volume intermediaries, and Panel C summarizes the Hasbrouck (1995) information share estimates. Information shares are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock.

**Panel A**

Quartiles	Number of underlying stocks	Number of stock days estimated	Client initiated		Market intermediary initiated - high-client-volume		Market intermediary initiated - low-client-volume	
			Proportion of trades	Proportion of volume	Proportion of trades	Proportion of volume	Proportion of trades	Proportion of volume
<b>Overall</b>	100	1802	61.1%	58.5%	12.2%	13.8%	26.7%	27.8%
<b>(Highest) 1</b>	25	474	59.3%	52.5%	9.7%	12.9%	31.0%	34.6%
<b>2</b>	25	473	58.8%	57.2%	12.7%	14.1%	28.5%	28.7%
<b>3</b>	25	444	59.2%	60.2%	13.8%	14.0%	26.9%	25.8%
<b>(Lowest) 4</b>	25	411	67.8%	64.9%	12.7%	14.2%	19.5%	20.8%

**Panel B**

Quartiles	Number of underlying stocks	Number of stock days estimated	Market intermediary - high-client-volume		Market intermediary - low-client-volume	
			Client initiated trades	Intermediary initiated trades	Client initiated trades	Intermediary initiated trades
<b>Overall</b>	100	1802	42.6%	13.8%	15.8%	27.8%
<b>(Highest) 1</b>	25	474	31.9%	12.9%	20.6%	34.6%
<b>2</b>	25	473	41.7%	14.1%	15.5%	28.7%
<b>3</b>	25	444	43.3%	14.0%	17.0%	25.8%
<b>(Lowest) 4</b>	25	411	55.4%	14.2%	9.5%	20.8%

**Panel C**

Quartiles	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated - high-client-volume		Market Intermediary initiated - low-client-volume	
			Min	Max	Min	Max	Min	Max
			<b>Overall</b>	100	1802	36.2%	42.3%	14.8%
<b>(Highest) 1</b>	25	474	31.5%	38.9%	8.7%	12.0%	50.5%	58.8% <sup>a</sup>
<b>2</b>	25	473	34.0%	39.7%	15.1%	18.4%	43.3%	49.7% <sup>a</sup>
<b>3</b>	25	444	39.6%	44.9%	14.7%	17.9%	38.6%	44.4% <sup>a</sup>
<b>(Lowest) 4</b>	25	411	40.3%	46.4%	21.5%	25.6%	30.4%	36.2% <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint of upper and lower bounds of low and high-client-volume intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

**Table 7: Information shares controlling for proportion of trades and volume by trader type: By number of analysts**

This table summarizes the results of Hasbrouck (1995) information share estimations controlling for proportion of trades and volume, separately for stocks with high and low analyst coverage. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. The ratios of information shares to the respective proportion of trades and volume are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for the sample divided into two halves based on the number of analyst estimates for the firm in September 2002 in the IBES database. The top half of the stocks have 16.3 analysts on average while the bottom half have 7.4. The six firms that do not appear in the IBES data are not included here. The difference between the midpoint of upper and lower bounds of the ratios for client and intermediary initiated trades is significant at the 1% level using the t-test of difference of means, as well as the linear rank sum z-statistic for the two sample test of difference of medians.

Halves	Number of stocks	Number of stock days estimated	Information share/Proportion of trades				Information share/Proportion of volume			
			Client initiated		Market Intermediary initiated		Client initiated		Market Intermediary initiated	
			Min	Max	Min	Max	Min	Max	Min	Max
<b>Overall</b>	94	1771	0.62	0.73	1.67	1.86	0.70	0.83	1.86	2.06
<b>High analyst coverage</b>	46	874	0.62	0.75	1.49	1.66	0.68	0.81	1.54	1.71
<b>Low analyst coverage</b>	48	897	0.62	0.72	1.85	2.05 <sup>a</sup>	0.73	0.86	2.18	2.40 <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians midpoint of upper and lower bounds of stocks with high and low analyst coverage is significant at the 1%, 5% and the 10% level respectively.

**Table 8: Information shares – March 2002**

This table summarizes the March 1, 2002 and March 27, 2002 sample, and the results of Hasbrouck (1995) information share estimations for this sample. We use trades in the 100 most liquid stocks between March 1, 2002 and March 27, 2002. Panel A summarizes stock characteristics. Panel B presents the proportion of trading initiated by clients and intermediaries, and Panel C summarizes the information share estimates. Information shares are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock.

**Panel A: Characteristics of stocks in the sample**

Quartiles	Number of underlying stocks	Number of stock days estimated	Average number of trades	Average Price	Average trade size	Average daily share volume
Overall	100	1850	431.8	30.2	1588.2	649,162.8
(Highest) 1	25	474	928.9	33.7	1317.5	1,270,743.7
2	25	467	369.6	37.2	1548.3	533,216.6
3	25	459	234.8	26.9	2183.8	524,724.8
(Lowest) 4	25	450	173.9	22.8	1307.2	241,684.0

**Panel B: Proportion of trades and volume by trader type**

Quartiles	Number of underlying stocks	Number of stock days estimated	Client initiated		Market intermediary initiated	
			Proportion of trades	Proportion of volume	Proportion of trades	Proportion of volume
Overall	100	1850	70.23%	63.55%	29.77%	36.45%
(Highest) 1	25	474	66.62%	56.25%	33.38%	43.75%
2	25	467	68.51%	62.04%	31.49%	37.96%
3	25	459	71.03%	65.33%	28.97%	34.67%
(Lowest) 4	25	450	74.98%	71.00%	25.02%	29.00%

**Panel C: Information shares by trader type**

Quartiles	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated	
			Min	Max	Min	Max
Overall	100	1850	36.55%	42.86%	57.14%	63.45% <sup>a</sup>
(Highest) 1	25	474	33.28%	41.20%	58.80%	66.72% <sup>a</sup>
2	25	467	35.28%	40.88%	59.12%	64.72% <sup>a</sup>
3	25	459	37.95%	44.16%	55.84%	62.05% <sup>a</sup>
(Lowest) 4	25	450	39.91%	45.35%	54.65%	60.09% <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint of upper and lower bounds of client and intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

**Table 9: Information shares-controlling for public information**

This table summarizes the results of Hasbrouck (1995) information share estimations. Information shares are calculated for each stock on each day in the sample for three price series: client initiated trades, intermediary initiated trades and midpoint of the bid-ask quotes. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock. Panel A presents the results for the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002, while Panel B presents the results for the 100 most liquid stocks between March 1, 2002 and March 27, 2002.

**Panel A: September 2002 sample**

Quartiles	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated		Quote midpoint	
			Min	Max	Min	Max	Min	Max
<b>Overall</b>	100	1870	9.97%	11.97%	17.09%	19.25% <sup>a</sup>	70.39%	71.36%
<b>(Highest) 1</b>	25	475	6.24%	8.79%	19.05%	21.85% <sup>a</sup>	71.37%	72.82%
<b>2</b>	25	475	7.52%	9.22%	15.33%	17.33% <sup>a</sup>	74.80%	75.83%
<b>3</b>	25	466	10.92%	12.74%	16.37%	18.22% <sup>a</sup>	70.49%	71.29%
<b>(Lowest) 4</b>	25	454	15.47%	17.40%	17.64%	19.62%	64.65%	65.24%

**Panel B: March 2002 sample**

Quartiles	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated		Quote midpoint	
			Min	Max	Min	Max	Min	Max
<b>Overall</b>	100	1850	9.48%	11.47%	16.34%	18.37% <sup>a</sup>	71.73%	72.68%
<b>(Highest) 1</b>	25	474	6.81%	9.34%	16.74%	19.41% <sup>a</sup>	73.13%	74.70%
<b>2</b>	25	467	7.63%	9.16%	15.35%	16.89% <sup>a</sup>	75.07%	75.93%
<b>3</b>	25	459	10.79%	12.81%	16.98%	19.05% <sup>a</sup>	69.84%	70.56%
<b>(Lowest) 4</b>	25	450	12.85%	14.72%	16.27%	18.10%	68.72%	69.36%

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint of upper and lower bounds of client and intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

**Table 10: Information shares – cross listed stocks**

This table summarizes the results of Hasbrouck (1995) information share estimations separately for stocks with a majority of their trading volume on the TSX and those with the majority of volume on US exchanges. We use trades in the 100 most liquid stocks on the TSX between September 3, 2002 and September 27, 2002. Information shares are calculated for each stock on each day included in the sample. These estimates are then averaged across stock days and presented here. Results are also presented separately for volume quartiles. A stock is assigned to a volume quartile based on the average daily number of trades in the stock.

Quartiles	Listing	Number of stocks	Number of stock days estimated	Client initiated		Market Intermediary initiated	
				Min	Max	Min	Max
<b>Overall</b>	TSX share<50%	19	357	37.1%	44.2%	55.8%	62.9% <sup>a</sup>
	TSX share>=50%	81	1513	38.6%	45.0%	55.0%	61.4% <sup>a</sup>
<b>(Highest) 1</b>	TSX share<50%	3	57	29.3%	38.4%	61.6%	70.7% <sup>a</sup>
	TSX share>=50%	22	418	31.9%	39.9%	60.1%	68.1% <sup>a</sup>
<b>2</b>	TSX share<50%	8	152	35.8%	42.9%	57.1%	64.2% <sup>a</sup>
	TSX share>=50%	17	323	35.6%	41.5%	58.5%	64.4% <sup>a</sup>
<b>3</b>	TSX share<50%	3	57	43.5%	50.4%	49.6%	56.5%
	TSX share>=50%	22	409	42.0%	47.7%	52.3%	58.0% <sup>a</sup>
<b>(Lowest) 4</b>	TSX share<50%	5	91	40.0%	46.0%	54.0%	60.0% <sup>c</sup>
	TSX share>=50%	20	363	45.2%	51.1%	48.9%	54.8% <sup>a</sup>

a,b,c indicate that the linear rank sum z-statistic for the two sample test of difference of medians of the midpoint of upper and lower bounds of client and intermediary initiated trades is significant at the 1%, 5% and the 10% level respectively.

## Appendix

### *The information shares methodology:*

We adapt the methodology developed by Hasbrouck (1995) to examine the information content inherent in trades of various market participants. Specifically, we consider two kinds of market participants: market intermediaries, and their clients. This approach assumes that prices of trades initiated by the two trader types for the same stock share a common random walk component - commonly referred to as the efficient price. The information share of transactions for a trader type is then measured as that group's contribution to the total variance of the random walk component.

Specifically, if we denote a price vector  $p$  that includes  $p_{ct}$ , the transaction price of a trade initiated by a client, and  $p_{it}$ , the transaction price of a trade initiated by an intermediary— for the same stock during a trading session - then we can express  $p_t$  as

$$p_t = \begin{bmatrix} p_{ct} \\ p_{it} \end{bmatrix} = \begin{bmatrix} V_t + e_{c,t} \\ V_t + e_{i,t} \end{bmatrix} \quad (\text{A.1})$$

The common efficient price  $V_t$  is assumed to follow a random walk given by

$$V_t = V_{t-1} + u_t \quad (\text{A.2})$$

where  $E(u_t) = 0$ ,  $E(u_t^2) = \sigma_u^2$ , and  $E(u_t u_s) = 0$  for  $t \neq s$ . Then, by the Granger Representation Theorem (see Engle and Granger (1987)), these cointegrated prices can be expressed as a vector error correction model of order  $N$  as:

$$\Delta p_t = A_1 \Delta p_{t-1} + \dots + A_N \Delta p_{t-N} + \gamma(z_{t-1} - \mu_z) + \varepsilon_t \quad (\text{A.3})$$

where  $p_t$  is a 2x1 vector of prices;  $A_i$  is a 2x2 matrix of autoregressive coefficients corresponding to lag  $i$ ;  $\gamma(z_t - \mu_z)$  is the error correction term, and  $\mu_z = E(z_t)$ . The covariance matrix of the error term above can be expressed as

$$\text{Cov}(\varepsilon_t) = E\varepsilon_t \varepsilon_t' = \Omega \quad (\text{A.4})$$

The vector moving average representation of the model given by equation (1) is:

$$\Delta p_t = B_0 \varepsilon_t + B_1 \varepsilon_{t-1} + B_2 \varepsilon_{t-2} + \dots, \text{ where } B_0 = I \quad (\text{A.5})$$

where  $\varepsilon$  is a 2x1 vector of zero-mean innovations with variance-covariance matrix given by  $\Omega$  which is of order 2x2. Also notice that in (A.5), the identity matrix  $I$  is 2x2, and the sum of all moving average coefficients  $B(1) = I + B_1 + B_2 + \dots$  has identical rows  $B$ . And since  $B$  reflects the impact of innovations on the permanent price component rather than transitory components, the total variance of the implicit efficient price changes can be expressed as  $\sigma_T^2 = B\Omega B'$ . Following Hasbrouck (1995), the contribution to price discovery by each trader type is expressed as that trader type's contribution to this total innovation variance.

Following Hasbrouck (1995), the information share of an intermediary initiated trade (say) is defined as:

$$IS_i = \frac{B_i^2 \sigma_i^2}{\sigma_T^2}$$

where  $B_i$  represents the element corresponding to intermediary initiated trades in the  $B$  vector.

However, if price innovations across client and intermediary initiated trades are correlated, then  $IS_i$  is not uniquely defined as above. Instead we estimate the upper and lower bounds, given by  $\overline{IS}_i$  and  $\underline{IS}_i$ , by performing Cholesky factorizations of all possible rotations (i.e., permutations) of the disturbance term,  $\varepsilon$ . The information shares for client initiated trades, are estimated similarly.

The estimation procedure involves building a second by second series of prices for client and intermediary initiated trades for each stock every trading day. We follow Hasbrouck in not including any inter-day price changes. Using this price vector, we estimate the VECM model in equation A.3 using a lag of 5 minutes (300 seconds). We set the number of periods in the VMA representation (to compute the impulse response functions) as 1,800 seconds. Hasbrouck suggests setting this number sufficiently high to allow forecasted prices to converge. We find that 30 minutes is sufficient for our data.