Three studies on Vector Autoregression measurement of information impounding in stock prices

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Abstract

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This thesis assesses the effectiveness of the Vector Autoregression (VAR) model to measure information flow by analyzing the relationships between stock price returns, patterns in the market data, and the Cumulative Impulse Response Functions (CIRFs) produced by the VAR model. Our understanding of the price discovery process is enhanced by the essays comprising this thesis which document the impact of trading patterns, passive order flow, and liquidity on information measurement, concluding that VAR models measure price volatility instead of informed trading.

The first essay "Sometimes a Trade is not a Trade: The Mismeasurement of Informed Trading" finds that trading patterns related to contrarian and momentum strategies partly explain the CIRFs despite not being related to permanent price changes. The influence of identifiable patterns in the market data challenge the information measurement veracity of the VAR model and imply that market practitioners cannot rely on simply trade sequencing to uncover information about asset prices. A secondary impact of these trading patterns is an underestimation of the endogenous trades forecast by the VAR model when price changes are characterized by increased proportions of contrarian trading activity, exacerbating the dissonance between the VAR model results and observed returns.

The second essay "Active Trading Patterns, Passive Order Flow, and Liquidity Impact on Information Measurement of Stock Trading" extends the VAR model by adding passive order flow variables. Passive orders are shown to have at least as much influence on the VAR model as active trades, countering the traditional view that information is transmitted by active orders. Analysis of the CIRF components reveals a complex interplay between active trades of different sizes and a variety of passive order flow types, suggesting that prices are formed by unique combinations of market activity instead of a singular trade sequence. An alternative analysis of the data that buckets stocks by liquidity concludes that liquidity, not price change, is the primary driver of the VAR model CIRFs, further calling into question the ability of the VAR model to measure informed trading.

The third essay "Microstructure information measurement with VAR Models: Price Discovery or Price Change?" delves further into the effect of liquidity and trading patterns on the VAR model. A new trading variable is introduced to isolate the impact of hidden orders on the VAR model, concluding that much of the endogenous order flow predicted by the VAR model is liquidity seeking instead of price revealing. The VAR model is then recomputed over subsets of data that incrementally move across the whole data set, allowing the VAR model's results to be analyzed against various return measures over the same data increments. The total amount of price change in the data contains substantially more explanatory power than the net price change, tying the VAR model's results to price volatility and not permanent price change caused by information impounding.

Declaration

I, Craig Geoffrey, declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

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Chapter 1: Introduction

1.1: Preface

Prior to embarking on the DBA, I worked for about a decade as a proprietary trader focused on Canadian and US equity markets. I witnessed first-hand the tech bust in 2000 and the financial crisis in 2008, along with the events that created notable trading periods, like 9/11, the Flash Crash, and the blackout of 2003. Each distinct period/event raised questions about the decision-making I was observing in the market and I became more and more curious about the rationale behind the opposing trading decisions (beyond my expected professional interest), particularly why a specific price was chosen as the point to buy or sell and why the direction of returns changed. After moving to a teaching role at the University of Waterloo in 2011, I thought more seriously about pursuing a research degree to try and answer my curiosity, which eventually led to the DBA program at The Alliance Manchester Business School. I have subsequently joined the faculty at the Rotman School of Management, University of Toronto where my teaching is primarily focused on financial trading strategies and market microstructure, for which I believe my combination of work experience and academic knowledge gained during the DBA has been beneficial.

1.2: Motivation

To paraphrase the opening line of Easley et al. (2002), asset-pricing is fundamental to our understanding of wealth. Greater life spans, with longer retirements, make the outcomes of investing increasingly important as we become more dependent on our savings. Asset prices, being determined in markets through the buying and selling of investors, incorporate the information held by investors about the value of the assets. Understanding the process by which information results in the prices we observe is therefore a fundamental input to the investment decision-making process on which so much now relies. This thesis explores the measurement of information flow into prices and the effect of trading patterns on the price impact of information.

When I started the DBA my academic literature exposure was limited to brief readings on prospect theory. My initial thoughts were to look at behavioral causes for the price action that I saw while trading. During the literature review, however, I read several articles about informed trading and information impounding. These articles seek to explain the proverbial footprints left by informed traders (O'Hara, 2015) with empirical analysis that was consistent with my experience and I shifted my research focus to information measuring models. The articles each had a different perspective on how to measure informed trading, including trading frequency with the Probability of Informed trade (PIN) of Easley et al. (1996), time between trades with Autoregressive Conditional Duration (ACD) from Engle and Russell (1998), and trade sequencing with Vector Autoregression (VAR) by Hasbrouck (1991). The VAR model resonated with me as I believed that the sequence of trades mattered for price changes, coming from a trading environment rife with heuristics like "first day up" and "don't catch a falling knife" that assumes the order of buy and sell trades contains information about future price changes. I narrowed my focus to the VAR model, and noticed that VAR was used frequently in literature to define anomalies, such as Ronen and Zhou (2013), that were interpreted as identifying informed trading. Criticism of informed trading measures appear in the literature, such as a critique of PIN (Duarte and Young, 2009) and a recent analysis of information measurement performance in Collin-Dufresne and Fos (2015) which concludes there is a discrepancy between the information measure and identifiable presence of informed traders in a market. This thesis adds to the literature by investigating the causes of the VAR measurement discrepancies identified in Collin-Dufresne and Fos (2015) and furthering our understanding of the price discovery process along a number of different angles. The primary research question is to determine if there are undiscovered endogenous patterns in the trading data (particularly patterns that I observed while trading, such as trades that cause a reversal of the trading direction or large bids and asks that cause trades to enter/avoid the market) that have an impact on our measurement of information flow into stock prices, and if so, how do those patterns affect the VAR model and our measurement of information impounding. If these patterns are meaningful, they may be added to the VAR model to improve its information measurement efficacy, contributing to the literature on information impounding and our understanding of price formation. A secondary objective is

to produce a deeper understanding of the mechanisms at work in the market and produce a more detailed picture of the steps or sequences that result from trading activity (the microstructure equivalent of mapping the ripples created by a rock hitting the surface of a pond), which adds to our understanding of the price discovery process by uncovering how the process works instead of only focusing on the outcome of the process.

The VAR model from Hasbrouck (1991) serves as the inspiration and starting point for the models explored in this thesis. VAR uses sequences of variables as inputs, but unlike a univariate autoregression model, each variable in a VAR model is explained by a combination of its own lagged observations and the lagged observations of other variables. The model from Hasbrouck (1991) includes a trade variable for shares bought or sold and a return variable for percentage changes in prices. The regression is estimated by the following formulas:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_k y_{t-k} + B_0 x_t + B_1 x_{t-1} + \cdots + B_k x_{t-k} + u_t \qquad \textit{(eq 1.1)}$$

$$x_t = C_1 y_{t-1} + C_2 y_{t-2} + \cdots + C_k y_{t-k} + D_1 x_{t-1} + \cdots + D_k x_{t-k} + v_t \qquad \textit{(eq 1.2)}$$

where y_t represents trades, x_t represents returns, and *A*, *B*, *C*, and *D* are the regression coefficients. The $B_0 x_t$ is included to account for the contemporaneous impact of trades on returns as the trading data is consolidated over short periods in some circumstances causing the trades and returns to occur at the same point in time in the data. Trades are assumed to cause returns, but not the opposite, which is why a similar term is not included in the estimation of x_t. Each trade and return, or price change, represents an event in the market. The lags in the model count the number of prior events that are included in the trade or return estimation. For example, y_{t-1} is the immediately prior return and y_{t-2} occurred two return events before the current event *t*. The variable *k* defines how many preceding events are included in the model. The sequence of events is independent of time, which has formed the basis of criticism and spurred the development of models that incorporate time, such as PIN and ACD.

After the parameters are estimated, an exogenous shock is applied in the form of a trade, with the resulting endogenous response measuring the impact, or information content, of the trade. Of particular interest is the cumulative change in price, or return, that occurs after the trade which is considered to be the price discovery process in action; the price changes represent the information content of the trade

being impounded by the market. The response evolves from the initial event, when the event index t = 0, until some number of events has elapsed. The number of events included in the response estimate is sufficient to reach the point where the response no longer changes materially. If a trade of 1,000 shares is used as the exogenous shock, we would have $x_0 = 1{,}000$ and $y_0 = B_0 1{,}000$. The subsequent event, at index *t* = 1, would incorporate trades and returns from the prior event; x_1 and y_1 include the results from x_0 and y_0, such that $x_1 = C_1 B_0 1{,}000 + D_1 1{,}000$ and $y_1 = A_1 B_0 1{,}000 + B_0(C_1 B_0 1{,}000 + D_1 1{,}000) + B_1 1{,}000$. This process continues until the desired number of events has transpired, at which point the cumulative return response is calculated by compounding the return series:

$$Cumulative\ Return = \left(1 + y_0\right)\left(1 + y_1\right) \ldots . \left(1 + y_k\right) - 1 \qquad \textit{(eq 1.3)}$$

The cumulative number of shares could similarly be calculated by summing the series of trades. Throughout this thesis, the response calculations are referred to as Cumulative Impulse Response Functions (CIRFs), with reference to the particular variable whose response is being calculated.

The first essay starts the analysis of the VAR model from Hasbrouck (1991) by focusing on the magnitude of the price impact of trades, measured by the CIRFs for the return variable, and patterns in the data that may affect our ability to measure the information content of a given trade by influencing the parameters estimated in the VAR model (Spencer, 1989). The trade variable is measured in multiple different forms, including the nominal number of shares, a signed indicator for buys and sells irrespective of volume, and aggregated volume measures that incorporate varied time frames, with conflicting differences in the return CIRFs for each trade variable confirming that the information measure is sensitive to the data inputs. Trades are then split into *Inflection* and *Non-Inflection* trades (the former are trades that are in the opposite direction and the latter are trades that are in same direction as the immediately preceding trade) which allow for the creation of trading pattern variables that measure the proportion of *Inflection* trading and the lengths of serially correlated buying and selling sequences. The trading pattern variables are then regressed against the return CIRFs from the VAR models to analyze the impact of the trading patterns on the VAR model's results. The trading variables have meaningful explanatory power for the return CIRFs and differing impact for different subgroups (cross-listed

stocks listed on the Toronto Stock Exchange (TSX) and a US exchange and non-cross-listed stocks listed only on the TSX) and subperiods (morning portion of a trading day vs. early and late afternoon periods), which expands on the existing literature by confirming the influence of trading patterns on the measurement of information impounding. The explanatory power of the trading patterns is problematic for the return CIRFs since they appear to impact the return CIRFs but do not have any relationship with the observed price changes, affecting the VAR model's information measurement accuracy. The effect of the trading pattern variables on the return CIRFs for the cross-listed and non-cross-listed groups are in the opposite direction, uncovering an additional complication for the VAR model which is the varying impact of the trading patterns depending on a stock's trading mechanism. The analysis concludes by reversing the trade-return causality to posit that returns cause trades, finding that returns produce commensurate adjusted R^2 as trades causing returns, providing a rationale for adding passive order flow to the model as passive changes in bid/ask prices could convey information to the market. The first essay concludes that patterns in the data impact the return CIRFs and establish the basis for the second and third essays, which conduct more detailed analysis of the trading patterns present in market data and the importance of expanding the VAR model to capture these trading patterns.

The second essay progressively introduces additional trading pattern variables into the VAR model to directly investigate their impact on the CIRFs. This essay contributes to the literature by drawing new conclusions about the importance of passive order flow, extending from the model in Brogaard et al. (2019), with new trading patterns derived from the contrarian (Campbell et al., 1993; Jegadeesh and Titman, 1995) and the stealth trading (Alexander and Peterson, 2007; Keim and Madhavan, 1995) literature. The sum of the analysis leads the essay to conclude that the VAR model measure of information flow does not necessarily relate to changes in stock prices in the way generally assumed in the literature. The first new VAR model adds passive order flow variables that measure changes to the size and price of the best bid and offer, thus including all order flow that affects the top of the book. The return CIRFs resulting from a trade impulse are lower than the model from the first essay, indicating that a portion of the observed price changes are attributable to passive order flow and models that only include active trades are

overestimating the price impact of those trades. Passive order flow that changes the price at the best bid or offer produces larger return CIRFs than active trades, suggesting that significant information measurement is missed in models that do not contain passive order flow. The components that generate the return CIRFs are analyzed to determine the underlying causes for the return CIRFs, uniquely adding to the literature by revealing the different mechanisms of price discovery estimated by the VAR model. Active trades, for example, generate most of their return CIRF directly from the initial trade impulse while passive orders have a more indirect influence (i.e. the passive order impulse is not the largest contributor to the return CIRF). This distinction is important, and the reason that the essay goes further into an analysis of the order flow CIRF components instead of limiting the research to the return CIRFs, as the market reaction to active and passive orders are indicators of the information content of each type of order and have material impacts on the return CIRFs we are using to judge the flow of information.

The *Trade* variable is split into *Inflection* and *Non-Inflection* trades, directly incorporating the trading pattern identified in Chapter 2 into the VAR model. The resulting return CIRFs indicate that *Inflection* trades contain similar information to *Non-Inflection* trades, possibly due to contrarian traders taking advantage of overreaction (Campbell and Kyle, 1993) or slow reaction (Chan et al., 1996) by uninformed traders, but raising questions about the importance of momentum in information impounding (i.e. an *Inflection* trade is the first trade in a sequence, by definition exhibiting no momentum, yet contains similar information to *Non-Inflection* trades that exhibit some degree of momentum). The results confirm the first essay's conclusion that trading patterns in the data are material to the VAR model and the ability to reduce the confounding nature of trading patterns by including them explicitly in the VAR model. Decomposition of the return CIRFs reveal unique mechanisms related to *Inflection* and *Non-Inflection* trades, contributing additional detail to the literature on price discovery. The *Inflection* and *Non-Inflection* trades are then replaced by trade variables that identify the size of the trade relative to the passive volume against which the trade executes. Trades are divided into three categories, based on whether the trade is *Greater Than, Equal To*, or *Less Than* the volume of the prevailing best bid or ask. Consistent with the stealth trading literature, the medium sized trades

(*Equal To* the best bid or ask volume) produce the highest return CIRFs (Chakravarty, 2001). Somewhat counter-intuitively, the *Less Than* trades have price impacts similar to the *Greater Than* trades, but this may be due to the significant endogenous trading activity cause by a *Less Than* trade impulse compared to *Equal To* or *Greater Than* trades. Again, the literature is enhanced by the CIRF decomposition that uncovers the mechanism driving the return CIRFs of the differently sized trades, identifying trades that rely on the direct effect of the initial trade impulse (*Greater Than* and *Equal To* trades) and trades that experience more price impact from endogenously generated trading activity (*Less Than* trades). The distinction is important for a measure of information if the market's reaction to the shock matters for its interpretation – if the market does not react beyond the direct impact of the initial trade impulse, it may not convey information in the eyes of the market, regardless of the price impact (which may be more related to filling passive bid and ask orders, resulting in a change in the quoted price). The final analysis in the essay rearranges the stocks in the dataset by liquidity, altering the summary statistics from the cross-listed/non-cross-listed subgroupings. The return CIRFs are inversely related to liquidity, with the most liquid subgroup's return CIRFs not only being materially lower than the less liquid subgroups, but also invariant to returns (some of which are significant). If returns are driven by information and the VAR model cannot detect differing levels of information, even when passive order flow is included which should incorporate public information, it may not be a useful measure of information impounding. These results suggest that information processing capacity or throughput is possibly related to liquidity, and different measurement methods or interpretations, based on liquidity, may be helpful.

The conclusions from the second essay lead to the two VAR model variations explored in the third essay. The first new VAR model adds a hidden order variable to analyze the differences in endogenous order flow revealed by the CIRF decompositions in the second essay. A new trade variable is created for trades that equal or exceed the size of the bid or ask when the trade is executed, but do not result in a change in the bid or ask price, thus revealing the presence of hidden volume in the form of an iceberg order. Consistent with the literature (Aitken et al., 2001; Frey and Sandås, 2009), the trades that encounter hidden liquidity generate substantial

endogenous trading, presumably to access the hidden liquidity. This result, combined with the CIRF decomposition that indicates a reduction of endogenous trading for trades that do not encounter hidden liquidity, adds to the literature by exposing the liquidity seeking nature of a portion of the endogenous trading spawned by trade impulses. This implies that the price impact of a singular trade series overestimates the information content of a trade impulse by conflating uninformed liquidity seeking follow-on trades with an interpretation that the trade is informed. The second new VAR model calculates return CIRFs for subsets of data that incrementally advance over the whole data set, creating a series of return CIRFs that react to the changing data in each subset. For example, the first subset may contain data in the first 500 observations in a data set of 15,000 observation (observations 1 through 500), with the second subset using observations 501 through 1,000, then a third subset using observations 1,001 through 1,500, and so on until the last subset which uses observations 14,501 to 15,000. For each subset of data, net (the percentage change between the first and last price observation in a subset) and absolute cumulative (the product of compounding the absolute return of every price change in the subset) returns are calculated; the return variables produce different measures of the "distance" travelled by the price in each subset, with the net return measuring the distance "as the crow flies" or the permanent price change and the absolute cumulative return measuring the total "road miles" travelled or the accumulation of temporary price changes incorporated into the permanent price change. The return CIRFs are then regressed against the return measures, with the regression results indicating that absolute cumulative returns have substantially more explanatory power for the return CIRFs than net returns. The implication is that the VAR model measures volatility, or the amount of trading activity as measured by the total price "distance" travelled, instead of the permanent price change resulting from information. This confirms the liquidity conclusion from the second essay, with the most liquid stocks having lower absolute cumulative returns than illiquid stocks as the less liquid stock see more volatile price activity due to traders seeking liquidity. The third essay concludes that the VAR model does not measure information related to an asset's price, but instead its liquidity and price volatility, perhaps as a measure of the total amount of price discovery "work" the market exerts to find a new

equilibrium price; the VAR model is closer to measuring information impounding efficiency than extent.

1.3: Thesis Structure

The thesis follows the journal format allowed by the University of Manchester's Presentation of Theses Policy and has been discussed and agreed with by my supervisors. The journal format allows Chapters to be presented in a format suitable for submission to and publication in peer-reviewed academic journals. The thesis is structured as three self-contained essays containing original work in Chapters 2, 3 and 4. Each Chapter addresses its own set of research questions and relies on separate literature, data, and methodology to generate its unique results and conclusions. Pages, sections, tables, and figures are numbered sequentially throughout the thesis.

The remaining Chapters in this thesis are as follows: Chapter 2 examines the effect of data and trading patterns on the CIRFs produced by VAR models. Chapter 3 expands the VAR model from Chapter 2 to investigate the impact of more complex trading patterns on the VAR model's CIRFs, with additional analysis on the effect of liquidity. Chapter 4 addresses questions about liquidity and the relationship between returns and CIRFs arising from the analysis in Chapter 3. Chapter 5 concludes the thesis.

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Chapter 2: Sometimes a Trade is not a Trade: The Mismeasurement of Informed Trading

2.1: Introduction

A fundamental concept underlying asset pricing is that prices reflect the information available to investors. The form of the information, and how it enters into asset prices, are debatable, but there is general acceptance that asset prices are not random. If this information determines prices, it must be valuable and so too a better understanding of how information is processed in the formation of prices (Biais et al., 2005; Madhaven, 2000; O'Hara, 2003). The value of information is based on it not being widely known, such that there are discrepancies between the market and private values of assets. To the extent that traders hold different information sets, they will trade differently (i.e. hold different portfolios of assets) as they act on their private incentives (Grossman and Stiglitz, 1980) and this will in turn affect asset prices and over time (albeit, possibly, incompletely) incorporate private values into market prices. Some of the private values will more accurately predict future market values. The actions of these "informed" traders are assumed to cause permanent changes in market prices (Glosten and Harris, 1988) as they buy *or* sell in accordance with their private information, unlike "uninformed" traders who buy *and* sell randomly, producing only temporary price changes that eventually reverse themselves. Changes in price act as a proxy for the information held by informed traders that we cannot directly observe.

Informed traders can express their information by trading passively, posting orders in the limit book, or actively, executing their orders against posted limit orders. The more valuable the information, the higher the opportunity cost of an unfilled passive order (Cohen et al., 1981). To minimize this opportunity cost, informed traders are expected to trade actively, making trades the primary conduit of information into the market. The combination of active trading and price changes are the focus of empirical studies of information impounding. Unfortunately, as noted

by Kyle (1985), noise traders camouflage informed traders in the market data, complicating the ability of empirical analysis to disentangle which market activity is informed. A number of models have been developed to estimate the information impounding process. Some of these models focus on the frequency of trade execution, such as the probability of informed trading (PIN) from Easley et al. (2002) and autoregressive conditional duration (ACD) from Engle and Russell (1998). Others use a time series approach, such as Vector Autoregression (VAR) from Hasbrouck (1991a), that rely on the sequencing of trades. More recent literature has expanded informed trading activity to include passive orders (Brogaard et al., 2019).

Given the importance of measuring information flows in markets, and the reliance on indirect methods, it is crucial that the measurement tools, such as VAR, do indeed measure what they purport to measure. There is emerging evidence that the information measurement tools generate unexpected results, for example producing lower measures of information when informed traders are known to be trading (Collin-Dufresne and Fos, 2015) or confusing illiquidity with information (Duarte and Young, 2009). This Chapter seeks to add to this area of investigation by explaining another reason why VAR results may be misleading, namely that sequences in the trading data that determine the coefficient estimates used to infer information content (Spencer, 1989) are not consistent with observed price changes. Here, the Cumulative Impulse Response Function (CIRF) estimated by the VAR model is used as the measure of information. The return CIRFs produced by a VAR model are not necessarily correlated with the level of observed price changes; if price changes are due to information impounding then it stands to reason that large price changes would indicate a large amount of information is impounded. An accurate measurement of information flow would be able to identify when a trader is acting on private information that indicates a large vs a small change in the expected value of a security's price. Uninformed traders, such as market makers, who face an adverse selection problem when trading with informed traders, are particularly interested in distinguishing between temporary price moves driven by illiquidity or behavioral biases from permanent price changes reflecting a change in an asset's value.

The key is the impact of trading patterns on the coefficient estimates from the VAR model. For example, in standard Ordinary Least Squares (OLS) estimation, the covariance depends on the degree of positive or negative serial correlation in trades and returns[1]. If there is a high degree of positive serial correlation then the coefficients are generally positive and the CIRF will indicate a (high) degree of information impounding (i.e. trades, which contain the information being impounded, will push prices in the direction of the trade/information – buy trades push prices up and sell trades push prices down). If the opposite is true, and the serial correlation is negative, then the return CIRF will not indicate the presence of information impounding. In the dataset, there is a tendency for the negative serial correlation to increase when there are greater changes in price over the course of the time period, including over the entirety of a day. Increases in negative serial correlation are caused changes in *Inflection* and *Non-Inflection* trading behavior. *Inflection* trades are those trades which are in the opposite direction from the immediately preceding trade. Changes in the frequency, size, and sequencing of these *Inflection* trades are shown to impact the return CIRFs independent of the change in price. In this regard, the VAR model measures the "smoothness" of trading activity, as opposed to its information content. This trading behavior has not been investigated, even in extensive surveys of summary trading statistics, such as Biais et al. (1995), with a similar lack of study of the impact on the CIRFs estimated by the VAR model. This Chapter provides an in-depth analysis of the trading behavior and demonstrates the implications for empirical analysis of information impounding. Since the CIRF calculation involves auto- and partial-correlation across multiple lags, the net effect of the *Inflection* trading pattern produces distinct differences in CIRFs across stocks and time periods. For example, there is a distinct difference in how *Inflection* trading behavior changes, or impacts, the CIRFs for stocks that are listed on two different exchanges (cross-listed stocks) versus stocks that are listed on only one exchange (non-cross-listed stocks).

[1] As illustrated in Appendix 2.2, the Maximum Likelihood Estimation and Generalized Method of Moments choose optimized parameters by minimizing the same sum of squared errors as OLS and produce the same coefficient estimates for linear regression. If the estimation methods produce the same coefficients, they must be similarly affected by the serial correlation in the trading sequence.

Small price changes with high degrees of trading homogeneity (positive serial correlation or a low proportion of *Inflection* trades) result in higher return CIRFs, and therefore higher information content, than large price changes with a higher proportion of *Inflection* trades. The price discovery process is messy, and the more a price moves, the messier the process. Relying on the emergence of non-random (or less random) trading sequences to identify information flowing into a market may be counter to the process being measured. If the trading patterns are endogenous, then treating all active trades as being equal in terms of information content is likely flawed. It may be that *Inflection* trades contain information while *Non-Inflection* trades simply carry the momentum from the *Inflection* trade. If so, an information measurement methodology would need to separately account for different types of trades, in terms of their behavior, such as separating *Inflection* and *Non-Inflection* trades into their own separate series. The relationship between *Inflection* trading patterns and the return CIRFs raise fundamental questions about information revelation and price movements. Do observed price changes cause traders to revise their trading behavior, or does observed trading behavior cause price revisions? Is there an impact on passive trading behaviour, as traders alter their passive orders (and therefore quoted bid/ask prices) in reaction to changes in active trading patterns, or the opposite? Does a larger change in price alter the proportion of uninformed traders in the market, and therefore the trading pattern, if the size of the price change affects its perceived likelihood as an over/under reaction?

Given the central importance of the trading sequence in investigating these questions, the first section provides a detailed discussion of the data used in this Chapter, followed by methodology. The analytical outcomes are discussed in the results section, with a robustness section examining the impact of the classification of *Inflection* trades. Implications of the results and comments about future research are contained in the conclusion and extensions sections.

2.2: Data

Since this Chapter is exploring the impact of data on the CIRFs estimated by the VAR model, the data discussion is divided into three parts. This section provides general information about the raw data used in the VAR models. Reflecting the diversity of data used in the literature, the next section (Data Structures) describes the different ways that the raw data is organized to produce the different datasets used in the VAR models. The third section, *Inflection* and *Non-Inflection* trades, details the *Inflection* trades that are the subject of this Chapter, along with summary statistics of the independent variables used in the regressions reported in the Results section.

The dataset includes trades and returns for 82 individual stocks that are listed on the Toronto Stock Exchange (TSX). 48 of the 82 stocks are also listed on the New York Stock Exchange or NASDAQ. These 48 stocks are included in the cross-listed subgroup, with the other 34 stocks comprising the non-cross-listed subgroup. The trade and return observations are drawn from the TSX' historical tick data which records all executed trades and NBBO price and volume. Executed trades are aggregated for the entire amount of the active portion of the trade (i.e. if a trade fills multiple passive orders, the total amount filled is recorded as a single trade) and returns are calculated as the change in the midpoint price (i.e. the average of the prevailing NBBO prices). Return observations are included whenever there is a change in the midpoint price as well as immediately following a trade. All trades are included in the data set, with buys coded positive (i.e. trade executes against the offer) and sells coded negative (i.e. the trade executes against the bid). The data covers all trades over the normal trading day (9:30am to 4:00pm) on March 18th and March 19th, 2009. The data includes a natural experiment in the form of an information shock. At 2:15pm on March 18th the FOMC announced its quantitative easing program, which caused a substantial move in the price of certain stocks, particularly gold mining companies. In addition to the cross-listed and non-cross-listed subgroups[2], the data is also divided into four time periods for each day: the Day subperiod covers 9:30am to 4:00pm, the Morning subperiod includes data from 9:30am to 11:59.59am, the Pre subperiod is from 12:00pm to 2:15pm, and

[2] Cross-listed is synonymous with interlisted in practitioner parlance.

the Post subperiod contains the remaining observations after 2:15pm to the close of trading at 4:00pm. The number of observations for each subperiod in the raw data is shown in Table 2.1.

Table 2.1: Total Observations, Trade Observations, and Return Observations by Subperiod

This table reports cross-sectional summary statistics for the trade and returns variables across the 82 stocks in the dataset. For example, under Total Observations for March 18th, the stock with the fewest total observations (combination of trade and return observations) has 1,083 trade and return observations and the mean number of total observations for all 82 stocks on March 18th is 17,033. The observations are divided into subperiods for each day (Morning = 9:30am to 11:59.59am, Pre = 12:00pm to 2:14.59pm, Post = 2:15pm to 4:00pm).

	Total Observations			**Total Trades**			**Total Returns**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
March 18th	1,083	99,324	17,033	239	29,036	5,651	408	87,712	11,382
March 19th	1,304	85,056	14,287	214	23,956	4,880	289	75,064	9,407

	Morning Observations			**Morning Trades**			**Morning Returns**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
March 18th	309	36,524	6,163	61	9,518	1,998	102	32,319	4,165
March 19th	427	46,699	7,979	75	15,553	2,575	221	41,113	5,403

	Pre Observations			**Pre Trades**			**Pre Returns**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
March 18th	185	15,263	2,613	42	4,758	960	48	13,645	1,653
March 19th	129	20,471	3,200	57	4,666	1,093	19	18,807	2,107

	Post Observations			**Post Trades**			**Post Returns**		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
March 18th	334	47,505	8,244	57	16,460	2,693	203	41,716	5,551
March 19th	265	17,872	3,099	61	4,919	1,211	35	15,130	1,888

2.2.1: Data Structures

Following in the spirit of the market microstructure literature, and providing additional sources of comparison, the raw data is organized into three different datasets (*Standard*, *Tradesign*, *Consolidated*). Each of these types of data organization are referred to as a data structure. Each data structure, as described below, has its own rules for adjusting the raw data. The differences between data structures will highlight the influence of *Inflection* trading as each creates a different pattern of activity. Hasbrouck (1991a) presents models that use an indicator variable

for trade direction (+1 for buys and -1 for sells) and trade size measured in shares, drawn from the same dataset. The results are not directly comparable as the models use different specifications (the model that includes share amounts is quadratic while the model with the trade indicator is strictly linear), however different share sizes produce different return CIRF patterns in terms of size and speed of the return response. We should expect the VAR model to produce different CIRF estimates depending on the inclusion or exclusion of trade size. In addition, although not directly applicable to the return CIRFs estimated in this chapter, Hasbrouck (2019) uses event time as well as data that is consolidated in a variety of time frames from 1 second down to 10 microsecond intervals. Different time frames and event time produce broadly similar results, such as quotes being more informative than prices, but the magnitude of the information measures changes between event time and the time frames. Shorter time frames correspond to higher statistical significance and higher information content attributable to particular sources of quote innovations. As noted by Brugler and Comerton-Forde (2019), longer time frames have difficulty pinpointing the source of the information in the data (i.e. which data feed is responsible for the observed price change), while shorter time frames are able to attribute the cause more precisely as the data more closely links action (trade or quote revision) and reaction (subsequent quote revision). Similarly, event time may contain events that are out of order if there are market participants who operate at a variety of speeds (Hasbrouck, 2019). For example, a trader who takes 10 microseconds to react could place a trade in the sequence before a trader who takes 1 second to react is even aware of the faster trader's trade, but an event time model would attribute the faster trader's order as the lag 1 trade.

Standard Data Structure

The *Standard* data structure is closest to the raw form of the data. It is constructed from the raw tick data by aggregating trades that are split among multiple passive buyers or sellers and eliminating odd lot trades. Aggregation simplifies the trades into a singular observation of the active trade's intent. For example, an aggregated trade that records buying 1,000 shares, assumed to be the intent of the buyer, is different in terms of data than buying 100 shares from

passive offer A, buying 400 shares from passive offer B, and buying 500 shares from passive offer C. Active trades are coded positive for buys and negative for sells. Odd lots are traded in a separate, odd lot only, book on the TSX, with all odd lot purchases and sales executed with the registered trader (market maker) for that stock. The registered trader can then offset their exposure in the board lot book. This may introduce a degree of mismatching trade flow. If the odd lot trades are significant and substantially on one side of the market, the *Standard* data structure will only record the registered trader's offsetting trades. Returns are calculated as the percentage change of the quoted midpoint. If the bid and ask are 10.00 and 10.10, respectively, then the midpoint is 10.05. If the midpoint changes to 10.07, the return is 0.199%.[3] In the raw data, each change in the market is recorded as a tick, whether or not there is a change in the quoted prices, such as changing volume on the bid or ask. The *Standard* data structure only records a return when there is a change in the midpoint. Additionally, midpoints are measured before and after each trade to generate a return tied directly to each trade. Returns of zero in these cases are included in the data structure. The return series, therefore, includes returns that are caused by trades (filling a bid or ask) as well as changes in the quote due to other causes. The explanatory power of missing variables may be attributed to trades or returns in unknown ways, skewing the resulting information measures. The data captures all the outcomes (price changes) of market activity, but only a partial set of the market activity itself (trades), which may result in attribution of influence to trades. The Extensions section presents further discussion of this point, and additional variables explore this issue in Chapters 3 and 4. The last quote before the first trade of the day is included in the dataset as the first midpoint for the return series. The first return is calculated from the first midpoint and does not include changes in the quote from the previous day's trading activity. The last observation of the data set is the last midpoint of the trading day, which means the last observation in the dataset is a return.

[3] Uses the simple calculation, 10.07/10.05 – 1 = 0.1990%, in the data. Logarithm changes will produce slightly different observations, ln(10.07/10.05) = 0.1988%.

Tradesign Data Structure

The *Tradesign* data structure is identical to the *Standard* data structure, but replaces the trade volumes with 1 or -1, for buys and sells respectively. A buy of 1,000 shares in the *Standard* data structure would be a buy indicator of 1 in the *Tradesign* data structure. Similarly, a sell of -1,000 shares in the *Standard* data structure would be a sell indicator of -1 in the *Tradesign* data structure. In all aspects the *Tradesign* data structure is identical to the *Standard* data structure (returns, number of observations).

Consolidated Data Structure

The *Consolidated* data structure aggregates the *Standard* data structure over 1-, 2-, 3-, and 5-minute time intervals. If the first-time interval starts at 9:30.00am, and extends for 5-minutes, the first interval ends at 9:35.00am. All trades occurring within this interval are summed, and the return is calculated between the first and last midpoints within this interval. The second interval begins at 9:35.01am and ends at 9:40.00am. All trades occurring in this interval are summed, and the return is calculated between the last midpoint of the preceding interval and the last midpoint of the current interval. Although the last midpoint could occur early in an interval, this does not misallocate returns between time periods as the last midpoint is defined as the last quote change within the interval; any change in the quote that generates a return must have occurred in the succeeding interval. The number of observations in the *Consolidated* data structure is determined by the time interval, not the trading activity. The TSX' trading day is 6.5 hours, or 390 minutes, in length. The number of observations for the *Consolidated* data structure are reported in Table 2.2. The relatively small number of observations for the *Consolidated* data structure, compared to the *Standard* and *Tradesign* data structures, produce unstable results in some of the VAR models, particularly for the non-Day subperiods. Outliers have been excluded from the regressions reported in the Results section.

Table 2.2: Consolidated data structure observations

The table below reports the number of observations for each consolidated dataset in each subperiod. For example, there are 390 1-minute observations (time periods) during a 6.5-hour trading day.

	Day	Morning	Pre	Post
Hours	6.5	2.5	2.25	1.75
Minutes	390	150	135	105
# of 1-minute periods	390	150	135	105
# of 2-minute periods	195	75	67.5	52.5
# of 3-minute periods	130	50	45	35
# of 5-minute periods	78	30	27	21

As noted in the Methodology section, the *Inflection* impact enters the OLS calculation through the covariance term. The average trade sizes, which would be used in the OLS calculations, are shown in Table 2.3. These average sizes can be compared to the average *Inflection* and *Non-Inflection* trade sizes in Tables 2.4 and 2.5, to illustrate that the sign of the covariance input is determined by the direction of the trade, not the average trade.

Table 2.3: Average trade volumes and returns

The following table presents the average trade sizes for each data structure, broken down by subperiod and subgroup. Buys are signed positive and sells are signed negative so that the sign of the average indicates whether the average trade was a buy or sell. The *Tradesign* data structure average is close to zero, indicating near parity in the number of buys and sells. Deviations from zero in the *Standard*, *1 Min*, *2 Min*, *3 Min*, and *5 Min* data structures are due to differences in the relative sizes of buy and sell trades.

	Average Trade Size - All Stocks					
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	25.5	0.0	493.5	987.0	1,480.6	2,467.6
Morning	11.3	0.0	53.0	106.0	158.9	264.9
Pre	57.8	0.1	143.8	296.7	435.7	721.0
Post	23.8	0.1	296.8	594.5	895.6	1,483.8
March 19						
Day	7.3	0.0	97.4	194.9	292.3	487.2
Morning	-14.8	0.0	-23.7	-47.5	-71.2	-118.7
Pre	43.9	0.0	98.7	199.2	299.7	493.4
Post	11.6	0.0	22.0	42.7	66.0	133.9

	Average Trade Size - Cross-Listed Stocks					
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	12.4	0.0	488.7	977.4	1,466.1	2,443.6
Morning	1.3	0.0	-45.4	-90.8	-136.2	-227.0
Pre	23.7	0.1	133.5	271.7	407.4	669.1
Post	16.7	0.0	400.6	817.9	1,217.6	2,002.9

March 19						
Day	15.3	0.0	111.1	222.2	333.3	555.5
Morning	-11.4	0.0	-55.7	-111.3	-167.0	-278.3
Pre	67.8	0.0	143.2	290.4	429.6	715.9
Post	10.9	0.0	23.6	42.5	70.7	158.7

	Average Trade Size - Non-Cross-Listed Stocks					
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	44.0	0.1	500.3	1,000.6	1,500.9	2,501.5
Morning	25.3	0.1	191.9	383.7	575.6	959.4
Pre	106.0	0.1	158.3	331.1	474.8	791.3
Post	33.8	0.1	150.2	285.8	450.5	750.9
March 19						
Day	-4.1	0.0	78.1	156.3	234.4	390.7
Morning	-19.6	0.0	21.3	42.6	63.9	106.6
Pre	10.3	0.0	35.9	70.6	110.9	179.3
Post	12.7	0.0	19.7	43.1	59.1	98.6

Inflection and Non-Inflection Trades

The contrarian/momentum trading literature suggests that *Inflection* trades (contrarian trades) are informed when trading against irrational noise traders who are causing price changes with no apparent rationale to the more informed traders (Campbell and Kyle, 1993) or are overreacting/extrapolating too far into the future the impact of new information (Lakonishok et al., 1994). In some cases, informed traders may take advantage of uninformed traders reacting too slowly (Lo and MacKinley, 1990), with delayed reaction related to information that is not specific to a firm while overreaction is initiated by firm specific information (Jegadeesh and Titman, 1995). *Inflection* trades have three characteristics that can impact the OLS calculations: size, frequency, and sequencing. Differences in these aspects can change the coefficients in the VAR model independent of the midpoint price changes. For example, an increase in the size of *Inflection* trades will increase the size of the negative products in the covariance sum. This section provides summary statistics and a description of the variables that represent *Inflection* trades in the CIRF regressions.

First, we need a definition of *Inflection* trade. For the regressions in this Chapter, an *Inflection* trade is a trade that has an immediately preceding trade that is in the opposite direction. *Inflection* trades could be buys preceded by sells or sells preceded by buys. *Non-Inflection* trades, conversely, are immediately preceded by a trade in the same direction. All trades are defined as either *Inflection* or *Non-Inflection*, with the sum of *Inflection* and *Non-Inflection* trades comprising all trades. *Inflection* trades and the immediately preceding trade are grouped together for the analysis in this section. The rationale for this definition is to capture all of the trades that will produce negative products in the auto-correlation covariance calculation in the size summary statistics (i.e. auto-regression calculations for trades). These trades bracket the change in the direction and include the last trade of one buying/selling trend with the first trade of the next selling/buying trend and capture the signalling effect of the last trade in the preceding trend as well as the signal of the first trade of the new trend. To illustrate the definitions, consider the following trading sequence: +100, +100, +100, -100, -100, -100. The fourth trade would be classified as an *Inflection* trade as the preceding trade has the opposite sign. The third trade, in addition to the fourth trade, are inputs into the negative product in the auto-correlation calculation. The second, third, fifth, and sixth trades in the sequence would all be defined as *Non-Inflection* trades (the first trade is ambiguous as it has no preceding trade). To avoid double counting, trades grouped with *Inflection* trades are excluded from *Non-Inflection* trades in this section (the last *Non-Inflection* trade in a *Non-Inflection* trade sequence), which then comprise trades that are inputs to only positive products in the auto-correlation covariance calculation. The average size of *Inflection* trades combined with the immediately preceding trade are shown in Table 2.4 while the *Non-Inflection* trades absent trades included with *Inflection* trades are shown in Table 2.5.

Table 2.4: Average volume of *Inflection* and immediately preceding trades

This table reports the average size of *Inflection* trades combined with the immediately preceding trade for each data structure, broken down by direction, subperiod, and subgroup. Trade direction is indicated by the sign of the average trade size, with buys reported as positive numbers and sells as negative numbers (i.e. the average size of a *Inflection* buy combined with the immediately preceding trade in the *Standard* data structure for all stocks during the day on March 18th is 456 shares, while the average *Inflection* sell combined with the immediately preceding trade in the *Standard* data structure during the day on March 18th is 486 shares). The *Tradesign* data structure uses an indicator variable instead of volume, the average of 1 or -1 is categorical.

Average *Inflection* and immediately preceding Buy Trade Size All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	456	1	2,990	4,805	6,716	9,874
Morning	445	1	3,044	5,048	6,687	10,464
Pre	484	1	2,047	3,436	5,016	7,037
Post	453	1	4,039	6,428	8,941	12,607
March 19						
Day	690	1	3,321	5,082	6,910	9,830
Morning	681	1	4,044	6,092	9,059	12,684
Pre	836	1	2,925	4,447	5,860	8,644
Post	552	1	2,745	4,384	4,986	7,523

Average *Inflection* and immediately preceding Buy Trade Size Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	386	1	3,297	5,101	7,177	10,511
Morning	390	1	3,050	4,581	6,197	9,916
Pre	428	1	2,163	3,511	4,787	6,661
Post	364	1	5,062	7,940	11,563	16,679
March 19		1				
Day	652	1	4,109	6,344	8,624	11,881
Morning	518	1	4,817	7,554	11,386	14,998
Pre	972	1	3,742	5,667	7,338	10,249
Post	514	1	3,569	5,563	6,230	9,559

Average *Inflection* and immediately preceding Buy Trade Size Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	554	1	2,556	4,388	6,065	8,974
Morning	523	1	3,035	5,706	7,378	11,238
Pre	563	1	1,884	3,329	5,340	7,566
Post	578	1	2,596	4,294	5,239	6,858
March 19						
Day	744	1	2,210	3,301	4,491	6,934
Morning	910	1	2,951	4,028	5,773	9,416
Pre	645	1	1,773	2,724	3,773	6,379
Post	606	1	1,582	2,721	3,231	4,648

Average *Inflection* and immediately preceding Sell Trade Size All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-486	-1	-2,549	-3,893	-5,035	-7,189
Morning	-509	-1	-2,813	-4,276	-5,677	-8,672
Pre	-481	-1	-1,666	-2,604	-3,494	-4,399
Post	-480	-1	-3,251	-4,875	-6,322	-8,670
March 19						
Day	-511	-1	-2,787	-4,362	-5,809	-8,278
Morning	-509	-1	-3,628	-5,847	-7,811	-11,532
Pre	-542	-1	-2,135	-3,158	-4,407	-6,041
Post	-500	-1	-2,393	-3,817	-4,668	-5,905

Average *Inflection* and immediately preceding Sell Trade Size Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-402	-1	-3,044	-4,556	-6,175	-8,908
Morning	-449	-1	-3,526	-5,369	-7,371	-11,614
Pre	-431	-1	-1,881	-2,903	-3,817	-4,469
Post	-350	-1	-3,852	-5,557	-7,713	-10,614
March 19						
Day	-423	-1	-3,309	-5,223	-7,221	-10,282
Morning	-412	-1	-4,351	-7,117	-9,776	-14,200
Pre	-479	-1	-2,492	-3,665	-5,381	-7,685
Post	-424	-1	-2,911	-4,568	-5,995	-7,386

Average *Inflection* and immediately preceding Sell Trade Size Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-605	-1	-1,850	-2,956	-3,426	-4,763
Morning	-594	-1	-1,807	-2,734	-3,286	-4,518
Pre	-550	-1	-1,363	-2,182	-3,037	-4,299
Post	-664	-1	-2,401	-3,911	-4,358	-5,925
March 19						
Day	-635	-1	-2,050	-3,147	-3,816	-5,449
Morning	-646	-1	-2,606	-4,055	-5,037	-7,766
Pre	-631	-1	-1,630	-2,441	-3,033	-3,720
Post	-608	-1	-1,661	-2,755	-2,794	-3,813

Table 2.4 shows the average combined *Inflection* and immediately preceding trade volume, in shares per trade. The average is across all 82 stocks in the study, for the cross-listed and non-cross-listed subgroups, and across the *Standard*, *Tradesign*, *1 Min*, *2 Min*, *3 Min*, and *5 Min* data structures. These are the average sizes of the individual trades and represent the size of the trade observations that will produce negative products in the autocorrelation covariance calculation in the OLS estimation.

Table 2.5: Average volume of *Non-Inflection* trades not grouped with *Inflection* trades

This table reports the average size of *Non-Inflection* trades excluding the trades grouped with *Inflection* trades in Table 2.4 for each data structure, broken down by direction, subperiod, and subgroup. Trade direction is indicated by the sign of the average trade size, with buys reported as positive numbers and sells as negative numbers (i.e. the average size of a *Non-Inflection* buy in the *Standard* data structure for all stocks during the day on March 18th is 430 shares, while the average *Non-Inflection* sell in the *Standard* data structure during the day on March 18th is 389 shares). The *Tradesign* data structure uses an indicator variable instead of volume, the average of 1 or -1 is categorical

Average Buy Size for *Non-Inflection* trades not grouped with *Inflection* trades All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	430	1	3,192	5,211	6,937	9,893
Morning	497	1	2,731	4,318	6,087	6,899
Pre	523	1	2,186	3,365	4,024	5,632
Post	356	1	4,657	7,325	10,282	15,791
March 19						
Day	418	1	3,219	5,498	7,646	11,459
Morning	453	1	4,509	8,132	10,514	15,384
Pre	409	1	2,305	3,949	5,027	5,664
Post	392	1	3,006	4,258	7,695	11,096

Average Buy Size for *Non-Inflection* trades not grouped with *Inflection* trades Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	286	1	4,004	6,691	8,892	12,307
Morning	305	1	3,474	5,727	7,882	8,593
Pre	296	1	2,404	3,797	4,721	6,416
Post	272	1	6,133	9,521	13,378	19,435
March 19						
Day	335	1	4,051	6,956	9,751	14,642
Morning	354	1	5,770	9,754	12,356	18,742
Pre	335	1	2,931	5,067	6,493	8,527
Post	334	1	3,830	5,668	10,448	15,238

Average Buy Size for *Non-Inflection* trades not grouped with *Inflection* trades Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	633	1	2,045	3,121	4,177	6,485
Morning	768	1	1,682	2,329	3,554	4,508
Pre	844	1	1,878	2,756	3,040	4,525
Post	476	1	2,572	4,225	5,911	10,647
March 19						
Day	535	1	2,044	3,439	4,673	6,964
Morning	591	1	2,729	5,841	7,914	10,644
Pre	513	1	1,421	2,370	2,958	1,621
Post	474	1	1,843	2,267	3,809	5,248

Average Sell Size for *Non-Inflection* trades not grouped with *Inflection* trades All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-389	-1	-2,869	-4,679	-5,697	-7,956
Morning	-434	-1	-3,260	-5,367	-6,762	-7,641
Pre	-380	-1	-1,641	-2,080	-2,425	-3,961
Post	-361	-1	-4,232	-6,696	-6,273	-7,119
March 19						
Day	-417	-1	-3,096	-5,095	-6,503	-10,336
Morning	-520	-1	-4,328	-6,921	-9,040	-13,565
Pre	-346	-1	-1,858	-3,291	-3,509	-6,380
Post	-361	-1	-2,529	-4,028	-4,690	-8,796

Average Sell Size for *Non-Inflection* trades not grouped with *Inflection* trades Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-295	-1	-3,520	-6,235	-7,052	-9,793
Morning	-361	-1	-4,178	-7,284	-8,752	-9,728
Pre	-293	-1	-1,813	-2,586	-2,960	-5,573
Post	-250	-1	-4,310	-9,099	-7,408	-6,131
March 19						
Day	-330	-1	-3,997	-6,776	-8,612	-13,371
Morning	-408	-1	-5,729	-9,002	-12,032	-19,193
Pre	-295	-1	-2,445	-4,467	-4,604	-5,998
Post	-294	-1	-3,106	-5,285	-5,945	-10,167

Average Sell Size for *Non-Inflection* trades not grouped with *Inflection* trades Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-523	-1	-1,950	-2,481	-3,785	-5,364
Morning	-536	-1	-1,963	-2,660	-3,954	-4,695
Pre	-504	-1	-1,399	-1,365	-1,669	-1,686
Post	-518	-1	-4,121	-3,303	-4,671	-8,513
March 19						
Day	-539	-1	-1,825	-2,723	-3,526	-6,051
Morning	-678	-1	-2,350	-3,982	-4,816	-5,620
Pre	-418	-1	-1,029	-1,629	-1,963	-6,920
Post	-457	-1	-1,714	-2,254	-2,919	-6,859

Table 2.5 shows the average *Non-Inflection* trade volume, in shares per trade, for *Non-Inflection* trades not grouped with Inflection trades in Table 2.4. The average is across all 82 stocks in the study, for the cross-listed and non-cross-listed subgroups, and across the *Standard*, *Tradesign*, *1 Min*, *2 Min*, *3 Min*, and *5 Min* data structures. These are the average size of the individual trades and represent the size of the *Non-Inflection* trade observations that will enter the positive products in the autocorrelation covariance calculation in the OLS estimation. Table 2.4 and Table 2.5 highlight five important points to note with respect to *Inflection* trading activity. First, there

are distinct differences in the trading patterns for the cross-listed and non-cross-listed subgroups. For example, in the Post subperiod on March 18 for the *Standard* data structure, the average size of the *Inflection* and immediately preceding trades for the cross-listed subgroup was lower than in other subperiods while the lowest average trade size for the non-cross-listed group was in the Pre subperiod. The net change for all stocks in the subperiod, however, appears minimal because the distinct changes in the subgroups are being masked when they are consolidated into one group. Differences in *Inflection* trading effects on distinct subgroups may signal the influence of liquidity or the presence of a related marketplace on trading patterns and their impact on the CIRFs estimated by the VAR model.

The second thing to note is that there can be substantial changes in trading behavior over the course of different subperiods, as reflected in the changes in average trade sizes. For example, the average size of *Non-Inflection* trades not grouped with *Inflection* trades in the *1 Min* data structure deviate significantly between subperiods. These changing patterns will feed into the VAR model and impact the resulting coefficients and subsequent information measures, as discussed at the end of this section. The third item of interest is the difference between buy and sell average trade sizes across some of the subperiods. For March 18, as an example, in the *5 Min* data structure the average buy size for *Non-Inflection* trades not grouped with *Inflection* trades increases while the sell size for *Non-Inflection* trades not grouped with *Inflection* trades decreases. In other cases (different subperiods or data structures) the change in buy and sell trade sizes are positively correlated. Since buys and sells for *Inflection* and immediately preceding and *Non-Inflection* trades not grouped with *Inflection* trades interact differently in the OLS calculations, these trading pattern variations can cause different VAR model coefficients despite covering the same subperiods and midpoint price changes. Fourth, there are distinct differences across the data structures. For example, the average trade size for *Inflection* and immediately preceding trade or *Non-Inflection* trades not grouped with *Inflection* trades between the Morning and Post subperiods is falling for the *Standard* data structure but is rising for the *1 Min* and *3 Min* data structures. This type of pattern divergence may, in part, explain why there are differences in the estimated CIRF parameters between data structures for different time periods. Finally, the

presence of multiple subperiods, data structures, and trade definitions (*Inflection* vs. *Non-Inflection*) leads to many potential interactions, some of which may be at cross-purpose. For example, the average *Inflection* and immediately preceding trade size may increase or decrease between subperiods at the same time that the trades size of *Non-Inflection* trades not grouped with *Inflection* trades increases or decreases, which could reinforce or cancel out their net impact on the VAR model coefficients. Another way to think about the relationship between the sizes of *Inflection* and immediately preceding trades and *Non-Inflection* trades not grouped with *Inflection* trades is through a ratio of trade size. Table 2.6 below reports the size ratios of *Inflection* and immediately preceding trades to *Non-Inflection* trades not grouped with *Inflection* trades, effectively converting the data from Tables 2.4 and 2.5 into a set of common size observations that can be used in the regression of return CIRFs against trading pattern data.

Table 2.6: Size Ratios of *Inflection* and immediately preceding trades to *Non-Inflection* trades not grouped with Inflection trades

This table reports the ratio of the average size of *Inflection* and immediately preceding trades to *Non-Inflection* trades not grouped with *Inflection* trades for each data structure, broken down by direction, subperiod, and subgroup. The ratio of the average size of a buy trade for *Inflection* and immediately preceding trades to the average size of a buy trade for *Non-Inflection* trades not grouped with *Inflection* trades in the *Standard* data structure for all stocks during the day on March 18th is 1.06 (the 456 entry from Table 2.4 divided by the 430 entry from Table 2.5) meaning the average size of a buy for *Inflection* and immediately preceding trades is 6% larger than the average buy size for *Non-Inflection* trades not grouped with *Inflection* trades). The *Tradesign* data structure uses an indicator variable instead of volume, the average of 1 or -1 is categorical.

	Average Buy Trade Size Ratios All Stocks					
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.06	1	0.94	0.92	0.97	1.00
Morning	0.90	1	1.11	1.17	1.10	1.52
Pre	0.93	1	0.94	1.02	1.25	1.25
Post	1.27	1	0.87	0.88	0.87	0.80
March 19						
Day	1.65	1	1.03	0.92	0.90	0.86
Morning	1.50	1	0.90	0.75	0.86	0.82
Pre	2.05	1	1.27	1.13	1.17	1.53
Post	1.41	1	0.91	1.03	0.65	0.68

	Average Buy Trade Size Ratios Cross-Listed Stocks					
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.35	1	0.82	0.76	0.81	0.85
Morning	1.28	1	0.88	0.80	0.79	1.15
Pre	1.45	1	0.90	0.92	1.01	1.04
Post	1.34	1	0.83	0.83	0.86	0.86

March 19						
Day	1.94	1	1.01	0.91	0.88	0.81
Morning	1.46	1	0.83	0.77	0.92	0.80
Pre	2.90	1	1.28	1.12	1.13	1.20
Post	1.54	1	0.93	0.98	0.60	0.63

Average Buy Trade Size Ratios Non-Cross-Listed Stocks

March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	0.88	1	1.25	1.41	1.45	1.38
Morning	0.68	1	1.80	2.45	2.08	2.49
Pre	0.67	1	1.00	1.21	1.76	1.67
Post	1.22	1	1.01	1.02	0.89	0.64
March 19						
Day	1.39	1	1.08	0.96	0.96	1.00
Morning	1.54	1	1.08	0.69	0.73	0.88
Pre	1.26	1	1.25	1.15	1.28	3.93
Post	1.28	1	0.86	1.20	0.85	0.89

Average Sell Trade Size Ratios All Stocks

March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.25	1	0.89	0.83	0.88	0.90
Morning	1.17	1	0.86	0.80	0.84	1.13
Pre	1.26	1	1.01	1.25	1.44	1.11
Post	1.33	1	0.77	0.73	1.01	1.22
March 19						
Day	1.23	1	0.90	0.86	0.89	0.80
Morning	0.98	1	0.84	0.84	0.86	0.85
Pre	1.56	1	1.15	0.96	1.26	0.95
Post	1.39	1	0.95	0.95	1.00	0.67

Average Sell Trade Size Ratios Cross-Listed Stocks

March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.36	1	0.86	0.73	0.88	0.91
Morning	1.24	1	0.84	0.74	0.84	1.19
Pre	1.47	1	1.04	1.12	1.29	0.80
Post	1.40	1	0.89	0.61	1.04	1.73
March 19						
Day	1.28	1	0.83	0.77	0.84	0.77
Morning	1.01	1	0.76	0.79	0.81	0.74
Pre	1.62	1	1.02	0.82	1.17	1.28
Post	1.44	1	0.94	0.86	1.01	0.73

Average Sell Trade Size Ratios Non-Cross-Listed Stocks

March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.16	1	0.95	1.19	0.91	0.89
Morning	1.11	1	0.92	1.03	0.83	0.96
Pre	1.09	1	0.97	1.60	1.82	2.55
Post	1.28	1	0.58	1.18	0.93	0.70

March 19						
Day	1.18	1	1.12	1.16	1.08	0.90
Morning	0.95	1	1.11	1.02	1.05	1.38
Pre	1.51	1	1.58	1.50	1.54	0.54
Post	1.33	1	0.97	1.22	0.96	0.56

The ratios make apparent the change in trading behavior that occurs over the course of the subperiods and across the different data structures. In some cases, the ratio changes by 50% or more between subgroups or subperiods, while in other cases the ratios change only marginal between subgroups or subperiods. This reinforces a potential problem with microstructure analysis – if prices are impacted by intermittent information impounding, but entire data sets are used, the noise could outweigh the signal and could contribute to the inconsistent relationship between return CIRFs and midpoint price changes noted in Table 2.9. The ratios also highlight the difference in trading patterns created by different data structures. The raw data is the same for all data structures, but consolidating the data into *1 Min*, *2 Min*, *3 Min*, and *5 Min* time periods has a marked effect on the ratio of trade sizes in Table 2.6. In most cases the consolidation serves to reduce the size of *Inflection* and immediately preceding trades relative to *Non-Inflection* trades not grouped with *Inflection* trades. This will feed into the OLS calculations in the VAR model, as discussed below, and could skew the VAR coefficients in the consolidated data structures relative to the *Standard* data structure. The *Tradesign* data structure provides a benchmark for the impact of size differences between *Inflection* and immediately preceding trades vs. *Non-Inflection* trades not grouped with *Inflection* trades, as there is no change in the relative size of the trades. In addition to relative trade size, *Inflection* and immediately preceding trades and *Non-Inflection* trades not grouped with *Inflection* trades also impact the VAR coefficient through their frequency. The proportion of *Inflection* and immediately preceding trades, expressed as a percentage of the total number of trades, representing the frequency of *Inflection* and immediately preceding trades for each data structure, is presented in Table 2.7.

Table 2.7: Proportion of *Inflection* and immediately preceding trades

The table below presents the proportion of the trade observations that are *Inflection* and immediately preceding trades for each data structure, broken down by subperiod, and subgroup. For example, 48.7% of the trade observations for all stocks in the *Standard* data structure during day on March 18th are *Inflection* and immediately preceding trades, with the other 51.3% being *Non-Inflection* trades not grouped with *Inflection* trades.

Proportion of *Inflection* and immediately preceding trades All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	48.7%	48.7%	35.5%	37.8%	40.6%	41.8%
Morning	48.9%	48.9%	35.1%	38.3%	41.2%	42.3%
Pre	49.6%	49.6%	34.1%	38.4%	42.4%	43.8%
Post	48.5%	48.5%	37.7%	36.4%	37.2%	38.4%
March 19						
Day	49.1%	49.1%	35.9%	39.4%	40.9%	42.2%
Morning	48.6%	48.6%	36.3%	38.9%	40.4%	41.3%
Pre	51.9%	51.9%	34.9%	40.6%	43.6%	44.9%
Post	48.3%	48.3%	36.7%	38.6%	38.2%	40.0%

Proportion of *Inflection* and immediately preceding trades Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	45.8%	45.8%	38.9%	39.2%	41.7%	41.6%
Morning	46.1%	46.1%	38.1%	39.3%	42.3%	41.9%
Pre	47.7%	47.7%	38.9%	41.2%	44.3%	43.8%
Post	45.5%	45.5%	40.2%	36.5%	37.7%	38.1%
March 19						
Day	45.1%	45.1%	39.3%	41.0%	42.1%	43.4%
Morning	46.0%	46.0%	39.0%	40.0%	41.7%	42.2%
Pre	46.1%	46.1%	39.0%	42.8%	45.7%	46.1%
Post	44.1%	44.1%	40.2%	40.1%	38.0%	41.6%

Proportion of *Inflection* and immediately preceding trades Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	52.7%	52.7%	30.6%	35.8%	38.9%	42.1%
Morning	52.8%	52.8%	30.9%	36.8%	39.8%	42.7%
Pre	52.2%	52.2%	27.5%	34.5%	39.7%	43.8%
Post	52.8%	52.8%	34.1%	36.1%	36.6%	38.9%
March 19						
Day	54.7%	54.7%	31.2%	37.2%	39.2%	40.4%
Morning	52.2%	52.2%	32.5%	37.3%	38.5%	40.0%
Pre	60.2%	60.2%	29.2%	37.5%	40.5%	43.0%
Post	54.3%	54.3%	31.9%	36.5%	38.4%	37.7%

The data in Table 2.7 reiterates the general conclusions from Tables 2.4 through 2.6. There are noticeable differences in the frequency of *Inflection* and immediately preceding trades between subperiods and data structures in, and across, the cross-listed and non-cross-listed subgroups. Since an increase in *Inflection* and immediately preceding trades frequency introduces more

negative products into the covariance calculation, these changes represent another way for *Inflection* trading activity to influence the VAR coefficients. Table 2.7 also illustrates another moving part in the calculation of the VAR coefficients. At the same time that the size of *Inflection* and preceding trades may be increasing or decreasing, the frequency of those trades could be increasing or decreasing. This could mitigate or exacerbate the effect that *Inflection* and immediately preceding trades have on the VAR model.

Although the frequency of *Inflection* and immediately preceding trades indicates the percentage of trades in which there is a change in direction, from a buy to a sell or vice versa, this is only part of the story. There may be different ways of mixing together the same proportion of *Inflection* and immediately preceding trades to produce different sequences of buys and sells. For example, *Inflection* and immediately preceding trades could evenly divide a dataset or be clustered at the beginning or end, producing different sequences of trades with the same frequency of *Inflection* and immediately preceding trades. To estimate this sequencing effect, average trade runs for buys and sells are calculated. A buy/sell run is defined as the number of consecutive buy/sell trades in a row, with buy and sell run lengths for each data structure in Table 2.8. This represents the persistence of trading activity and provides additional information to the frequency data in Table 2.7. In some cases, the runs data reveals information that is obscured in the frequency data. For example, on March 18 the Morning subperiod for the *Standard* data structure has the shortest average Buy trade run length and the longest Sell trade run length but a similar proportion of *Inflection* and immediately preceding trades to other subperiods. The average trade run implied by the frequency data masks the difference in buy and sell trade run lengths. There is more positive serial correlation in data with longer trade lengths which could influence the information measure (or its interpretation) if trade run lengths correlate with price changes.

Table 2.8: Average Buy and Sell Run Lengths

The following table presents the average length of uninterrupted buy and sell trade sequence for each data structure, broken down by subperiod, and subgroup. For example, the average number of sequential buy trades in a row for all stocks in the *Standard* data structure during the day on March 18th is 3.8. Each trade sequence, or run, consists of an *Inflection* trade followed by some number of *Non-Inflection* trades; the shortest trade sequence would be composed of a single *Inflection* trade. The number or proportion of *Inflection* trades in the data defines the number of trade sequences. The *Standard* and *Tradesign* data structures have the same proportions of *Inflection* trades and therefore the same trading sequences. The *Consolidated* data structures alter the number and proportion of *Inflection* trades in the aggregation process, generating different trade sequence data.

Average Buy Trade Run Length All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	3.8	3.8	2.7	2.7	2.6	2.6
Morning	3.6	3.6	2.7	2.6	2.4	2.4
Pre	3.8	3.8	2.7	2.7	2.6	2.6
Post	3.9	3.9	2.8	3.3	3.3	3.2
March 19						
Day	3.2	3.2	2.3	2.4	2.3	2.4
Morning	3.0	3.0	2.2	2.2	2.1	2.2
Pre	3.3	3.3	2.4	2.5	2.5	2.7
Post	3.5	3.5	2.5	2.6	2.8	2.8

Average Buy Trade Run Length Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	3.9	3.9	2.6	2.7	2.5	2.6
Morning	3.7	3.7	2.6	2.6	2.4	2.4
Pre	3.8	3.8	2.4	2.5	2.4	2.6
Post	4.1	4.1	2.7	3.3	3.2	3.4
March 19						
Day	3.5	3.5	2.2	2.3	2.3	2.3
Morning	3.2	3.2	2.2	2.2	2.2	2.1
Pre	3.7	3.7	2.3	2.3	2.4	2.4
Post	3.7	3.7	2.2	2.4	2.7	2.8

Average Buy Trade Run Length Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	3.6	3.6	2.9	2.8	2.7	2.5
Morning	3.5	3.5	2.7	2.6	2.4	2.3
Pre	3.8	3.8	3.1	3.0	2.8	2.6
Post	3.7	3.7	3.0	3.2	3.4	2.9
March 19						
Day	2.8	2.8	2.5	2.5	2.4	2.5
Morning	2.6	2.6	2.3	2.2	2.1	2.3
Pre	2.7	2.7	2.6	2.7	2.7	3.2
Post	3.2	3.2	2.8	2.9	2.9	3.0

Average Sell Trade Run Length All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-2.9	-2.9	-2.1	-2.1	-2.0	-2.0
Morning	-3.0	-3.0	-2.2	-2.3	-2.2	-2.2
Pre	-2.8	-2.8	-2.1	-2.1	-2.0	-2.0
Post	-2.8	-2.8	-2.0	-2.0	-2.0	-1.8
March 19						
Day	-3.4	-3.4	-2.4	-2.4	-2.4	-2.3
Morning	-3.7	-3.7	-2.6	-2.6	-2.7	-2.8
Pre	-3.0	-3.0	-2.3	-2.1	-2.1	-2.0
Post	-3.3	-3.3	-2.4	-2.5	-2.5	-2.7

Average Sell Trade Run Length Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-3.2	-3.2	-2.1	-2.1	-2.0	-2.0
Morning	-3.2	-3.2	-2.2	-2.3	-2.2	-2.2
Pre	-3.0	-3.0	-2.1	-2.1	-2.0	-2.1
Post	-3.2	-3.2	-1.9	-2.0	-2.0	-1.8
March 19						
Day	-3.7	-3.7	-2.3	-2.3	-2.3	-2.2
Morning	-3.9	-3.9	-2.5	-2.6	-2.6	-2.7
Pre	-3.4	-3.4	-2.2	-2.2	-2.1	-2.0
Post	-3.8	-3.8	-2.3	-2.4	-2.4	-2.5

Average Sell Trade Run Length Non-Cross-Listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	-2.5	-2.5	-2.1	-2.1	-2.0	-1.9
Morning	-2.6	-2.6	-2.2	-2.2	-2.2	-2.2
Pre	-2.5	-2.5	-2.1	-2.1	-2.0	-1.9
Post	-2.3	-2.3	-2.0	-2.1	-2.0	-1.8
March 19						
Day	-2.9	-2.9	-2.4	-2.4	-2.4	-2.5
Morning	-3.5	-3.5	-2.7	-2.7	-2.8	-3.0
Pre	-2.5	-2.5	-2.3	-2.1	-2.1	-2.1
Post	-2.6	-2.6	-2.4	-2.5	-2.7	-3.1

Similar to the trade size and frequency data, the trade run length information illustrates the changing pattern of trade over the course of different subperiods, between data structures, and across the cross-listed and non-cross-listed subgroups. There is an additional consideration with respect to the data structures. The sequence of observations is different between the *Standard*/*Tradesign* data structures and the *Consolidated* data structures. Each row in the *Standard* and *Tradesign* data structures preserves the sequential ordering of the raw data and has only one observation, a trade or a return; if there is a return then the trade observation must

equal zero, and vice versa. The *Consolidated* data structure's aggregation means there will be both returns and trades on the same row (i.e. at the same time). For the *Consolidated* data structure, an average trade run of 3 means three consecutive trades over three consecutive observations. For the *Standard* and *Tradesign* data structures, however, an average trade run of 3 could occur over 6 or more consecutive observations. This may produce a difference in the impact of trade runs between the data structures as the additional spacing between *Standard* and *Tradesign* trades in a run may dilute the VAR coefficient calculations by requiring a greater number of lags to capture the same trading run length, spreading the trade impact over a greater number of coefficients and weakening the effect size.

Having a sense of the ebb and flow of the *Inflection* and immediately preceding trading activity in the data, we now turn to the impact of these patterns on the VAR coefficients and return CIRFs. The Results section contains the regressions output of the return CIRFs against the measures of *Inflection* and immediately preceding trading activity outlined in this section, with the remainder of this section discussing the expected outcome of the regressions. In general, we are testing how the data's organization influences the coefficients generated by the VAR model. Imagine two stocks that are identical in every way, including their respective price changes, but which have systematic differences the size and/or frequency of their *Inflection* and immediately preceding trades. The stock with greater size and frequency of *Inflection* and immediately preceding trades would register a lower information measure even though the two stocks have the same price changes. The average size of these negative products is affected by the size of the trades in the negatively related pairs. Larger *Inflection* and immediately preceding trades, the source of the negative serial correlation, will increase the size of the negative product. From Table 2.4, the average buy size for *Inflection* and immediately preceding trades for March 18th in the Morning subperiod for the Cross-Listed subgroup is 390 with the average sell size for *Inflection* and immediately preceding trades for the same subsample being -449. On average, in the OLS calculation, these two numbers would be multiplied together to generate an average product of 390 x -449 = -175,110. The corresponding positive products from the *Non-Inflection* trades not grouped with *Inflection* trades would be 305^2 = 93,025 and -361^2 = 130,321, for average buy and

sell trades for *Non-Inflection* trades not grouped with *Inflection* trades from Table 2.5. The greater size of the *Inflection* and immediately trades give them more weight in the OLS calculations and produce a lower, more negative, coefficient. In looking at the *Inflection* and immediately preceding trades data, we would expect to see lower return CIRFs when there is an increase in the relative size of *Inflection* and immediately preceding trades and higher return CIRFs when the relative size of *Inflection* and preceding trades is lower, as noted in Table 2.6.

The covariance summation in the OLS calculation would include these products in accordance with their proportion in the data. The greater the proportion of *Inflection* and preceding trades in the data, the greater the impact of the relative size differences between *Inflection* and immediately preceding trades and *Non-Inflection* trades not grouped with *Inflection* trades. The *Inflection* and immediately preceding trades frequency, therefore, can exacerbate or mitigate the impact of relative trade size differences. It is not clear how changes in *Inflection* and immediately preceding trades frequency will affect the return CIRFs as it works hand-in-hand with the relative trade size differences. Trade sequencing, as representing by the trading run data, will also drive the OLS calculation by increasing or decreasing the number of positively serially correlated (i.e. *Non-Inflection*) trades. This data point interacts with the relative sizing information and frequency data, but in an unambiguous way. Longer trading runs should increase the number of positively serially correlated observations in the data and therefore the number of positive products in the covariance calculation. We should see a positive relationship between trade run length and return CIRFs. As an additional test, the inclusion of the *Tradesign* data structure helps to explore the impact of the relative trade size variable by removing this ratio from the *Tradesign* VAR model, as all trades are the same size. Otherwise, the data sets are identical, with the same *Inflection* and immediately preceding trades frequency and sequencing. As a consequence, if *Inflection* trading activity impacts the return CIRFs, we should observe less of an impact for the *Tradesign* data structure as we have removed one of the mechanisms for this impact. In summary, we observe different *Inflection* trading patterns across subperiods, subgroups, and data structures. With respect to the data structures, the differences are despite the fact that the data structures are all constructed from the same raw tick data. If these trading pattern

differences influence the VAR coefficients, and thereby the measure of information flow, then the VAR based information measure contains a systematic bias. The regression results in the next section will test this question.

2.3: Methodology

VAR was introduced to market microstructure analysis by Hasbrouck (1991a). Since its introduction, VAR has become ubiquitous in the microstructure literature, often used as a benchmark to judge informed trading. The attraction of VAR is the ability to create complex models that endogenously include interactions between input variables. This was the impetus behind its origination by Sims (1980), who was looking for a way to test large macroeconomic models without the need to impose restrictions on, or introduce assumptions about, the parameters in the model. In Sims' view, different restricted models used by macroeconomists could be validated by the same data; there was no way for the data to differentiate between restricted models that made contradictory assumptions. The solution was to eliminate the restrictions in the model by making all of the variables endogenous. Instead of assuming the relationship between interest rates and output, then modelling output, the VAR model would allow for the relationship between interest rates and output to be determined by the model. Sims concluded that the endogenously determined relationships differed in many cases from those imposed by restriction.

One of the more inspired thoughts behind VAR was the shift away from parsimonious to profligate model building. As noted by Sims, the worst-case scenario with a profligate model is an increase in the number of statistically insignificant coefficients; the worst case in a parsimonious, but restricted model, is an erroneous conclusion. This spirit may partly rely on the reduced emphasis on traditional statistical measures of fit, like coefficient T-tests or R^2, which become unreliable in the presence of endogenous variable interaction. VAR results focus on broader measures of effect, like the impulse response function and Granger causality tests (Stock and Watson, 2001). The limit to the complexity of the VAR model rests with the size of the data

set. Since "the number of parameters grows with the square of the number of variables" (Stock and Watson, 2001) the model's degrees of freedom can quickly be exhausted. This is not a limitation when using tick data, where massive data sets are available, although it may be a problem when the tick data is consolidated into set time periods (i.e. 1-minute blocks of time).

The VAR models are used to estimate the relationship between trades and returns. Once these relationships are estimated, the coefficients are used to find the return CIRF for a given trade shock. We focus on the return response to a trade impulse (the return CIRF), but the trade response to a trade impulse (trade CIRF) is discussed in the Robustness section. The *Standard* and *Tradesign* VAR models are estimated with the following equations[4]:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_k y_{t-k} + B_1 x_{t-1} + B_2 x_{t-2} + \cdots + B_k x_{t-k} + u_t \quad \textit{(eq. 2.1)}$$
$$x_t = C_1 y_{t-1} + C_2 y_{t-2} + \cdots + C_k y_{t-k} + D_1 x_{t-1} + D_2 x_{t-2} + \cdots + D_k x_{t-k} + v_t \quad \textit{(eq. 2.2)}$$

where y_t represents returns and x_t represents trades, and *A*, *B*, *C*, and *D* are the regression coefficients. To estimate the return CIRF, we need to know the coefficients for both y_t and x_t, as the initial trade shock can cause subsequent trades that will feed into the return CIRF. For example, a trade of 1,000 shares at time 0 would initially enter into the y_t and x_t equations at time 1, becoming the x_{t-1} observations. At time 2, the initial trade impulse would now be the x_{t-2} observation, with the x_{t-1} and y_{t-1} observation being the result of the trade that occurred at time 0. After this point in time, the lagged observations for both trades and returns will be caused by both preceding trades and preceding returns. This produces a number of cross-effects that are more complicated than can be ascertained by observing the coefficients, which motivates the reporting of return CIRFs instead of VAR model coefficients.

[4] Hasbrouck's VAR models included a contemporaneous term in the independent variables. Hasbrouck's dataset consolidated trades over a 15 second period, necessitating the possibility that the trade and return (quote revision) would occur at the same "t" in the dataset (each row in the dataset includes both trade and return entries). The trade-then-return sequence is imposed in the VAR model by explicitly defining the contemporaneous term to allow trades to cause returns but not the opposite. The *Standard* and *Tradesign* datasets in this article uses ticks instead of time and there is no overlapping in the sequence (each row in the dataset includes either a trade or a return entry) and therefore no need to explicitly define the direction of the contemporaneous relationship. The assumption that trades cause returns but not the opposite would seem to contradict the idea of information impounding, that markets react (presumably with trading activity) to price changes/returns.

Once the returns are calculated at each tick in the forecast period, they are compounded together to determine the total return response to the trade impulse to produce the return CIRF. If the return CIRF is non-zero and in the same direction as the trade impulse, it implies that the trade impulse has a permanent impact on prices, which is interpreted as being due to the information content of the trade. If the return CIRF is zero, or non-zero but in the opposite direction of the trade impulse, then the trade contained no information as the market ignored the signalling effect of the trade (presumably a buy/sell contains information that prices are too low/high). The *Standard* and *Tradesign* data structures produce positive return CIRFs, while the *Consolidated* data structures experience an increasing proportion of negative return CIRFs as the amount of time in the consolidation increases (Appendix 2.1). An increasing proportion of negative return CIRFs influences the reported average return CIRFs and could indicate an issue with the vector autoregression using fewer observations in its calculations. The serial correlations in the tick data may also be lost in the *Consolidated* data structures if the positive correlation is captured within the consolidation period, which is exacerbated as the consolidation period increases. There may also be an issue with the use of the contemporaneous term in the vector autoregression, discussed below.

The return CIRFs reported in this Chapter cover 100 events/time periods, with the first event/time period containing the trade impulse. The return CIRFs tend to stabilize within a short period of time, with 100 ticks ensuring that the reported return CIRFs have squeezed out all of the permanent changes in price resulting from endogenously generated trades and returns. The original VAR models developed by Sims assumed that there were no contemporaneous effects between the variables. This assumption is modified in the market microstructure context when tick data is consolidated into specific time periods. Ticks, by definition, are purely sequential – only 1 variable is observed for each tick and therefore at any point in time. When these ticks are consolidated over a period of time, such as 1 minute, then the consolidated data will contain contemporaneous effects as the trades and returns are occurring over the same time period. A model that only includes lagged variables will exclude this information and produce questionable

results. Including the contemporaneous effect in both directions, that is assuming that trades cause returns when they occur in the same time period, and vice versa, means the error terms will no longer have a covariance of zero. To correct for this, a structural VAR model (SVAR) is used which assumes that trades cause returns but returns do not cause trades (Hasbrouck, 1991a). For the *Consolidated* datasets, the estimated equations are:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_k y_{t-k} + B_0 x_t + B_1 x_{t-1} + \cdots + B_k x_{t-k} + u_t \qquad \textit{(eq 2.3)}$$

$$x_t = C_1 y_{t-1} + C_2 y_{t-2} + \cdots + C_k y_{t-k} + D_1 x_{t-1} + \cdots + D_k x_{t-k} + v_t \qquad \textit{(eq 2.4)}$$

where y_t represents returns and x_t represents trades, and *A*, *B*, *C*, and *D* are the regression coefficients. The $B_0 x_t$ term represents the contemporaneous impact of trades on returns.

Inflection and immediately preceding trades impact the VAR coefficients through the covariance term of the OLS calculation. As noted in Table 2.3 in the Data section, the average trade size is very close to zero or significantly smaller than the average buy or sell trades observed in the *Inflection* and immediately preceding trades and *Non-Inflection* trades not grouped with *Inflection* trades data (Tables 2.4 and 2.5). This means the signs of the trade observations will determine the sign of each product summed in the covariance calculation. In situations where there is positive serial correlation between observations, the product will be positive, and in situations where there is negative serial correlation, the product will be negative. The size and direction of the coefficient will depend on the degree of positive vs. negative serial correlation in the data. *Inflection* and immediately preceding trades, by their definition, introduce negative serial correlation into the data. If there is a systematic difference in the size, frequency, and sequencing of observations that are negatively serially correlated, we would expect there to be a systematic effect on the VAR model's coefficients and the resulting return CIRFs. Larger *Inflection* and immediately preceding trades would produce larger negative products in the covariance sum and thereby lower (or more negative) coefficients and lower (more negative) return CIRFs. Similarly, an increase in the frequency of *Inflection* and immediately preceding trades and/or reduction in the average number of observations between *Inflection* trades, indicates an increase in the number of negative products in the covariance sum and lower return

CIRFs. The impact of *Inflection* and immediately preceding trades on the calculation is complicated by the number of lags included in the VAR model and our interest in the cross-correlation between trades and returns (as opposed to the autocorrelation between trades and trades). The net impact of *Inflection* and immediately preceding trades will be tested by regressing the return CIRFs from the VAR model against the size, frequency, and sequencing of *Inflection* and immediately preceding trades (see *Inflection* and *Non-Inflection* data section):

$$Return\ CIRF_t = Intercept +$$
$$b_1 Proportion\ of\ Inflection\ and\ immediately\ preceding\ trades_t + b_2 Average\ Buy\ Run_t +$$
$$b_3 Average\ Sell\ Run_t + b_4 Size\ Ratio\ for\ Buys_t + b_5 Size\ Ratio\ for\ Sells_t + \varepsilon_t \qquad \textit{(eq 2.5)}$$

The results of this regression for the different subgroups and subperiods outlined in the Data section are included in the Results section. If the trading pattern defined by the proportion of *Inflection* and immediately preceding trades does not affect the return CIRFs, the coefficients in the regression should be statistically insignificant. Of particular interest is the significance of the *Inflection* and immediately preceding trades as a percent of all trades' coefficient, as the most general measure of differences in trade sequencing.

2.4: Results

The problem with the standard VAR methodology for measuring information flow is illustrated in Table 2.9. The first column of each panel reports the average percentage change in the midpoint price of different subgroups of stocks over different time periods, as described in the Data section. The remaining columns contain the average return CIRFs resulting from a trade impulse for the various forms of data organization (see the Data Structures section). Comparing the change in the midpoint prices, which we are interpreting as the permanent price change from the market microstructure literature, with the return CIRFs, the measure of information flow, reveals a disconnect between price changes and information flows; there is no apparent correlation between price changes and information flow. For example, for the all stock subgroup on March 18, the price change in the Morning is less than half that in the Post period, but the

return CIRFs are greater in the Morning for the *Standard* and *Tradesign* data structures. The same pattern occurs for the *1 Min* and *3 Min* Cross-Listed subgroups on March 19. In other cases, the relative changes in price are mirrored by the relative change in the return CIRF. The information measure makes logical sense, on a prima facia basis, only some of the time. This is a bad characteristic for a measurement tool – imagine a ruler that measured out different lengths that were all labelled 10 cm. If the theory that information forms prices is correct, then the measurement of information should be consistent, and we can investigate why the measurement tool is producing unreliable results.

Table 2.9: Midpoint % Change and Return CIRFs

This table reports the return CIRFs for trade impulses in each of the data structures broken down by subperiod, and subgroup. The average change in the Midpoint prices is presented for comparison purposes, constituting the average change in midpoint price from the first to last price observation. The trade impulses are a 1,000 share buy trade that cause a return response measured over a 100-tick period. For example, a 1,000 share buy trade in the *Standard* data structure induces an average price change across all stocks of 0.089% after 100-ticks during the day subperiod on March 18th.

Return Response to Trade Impulse - All Stocks							
		Average Return CIRFs					
March 18	Midpoint % Change	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.795%	0.089%	0.051%	0.043%	0.039%	0.032%	0.040%
Morning	-0.809%	0.094%	0.053%	0.061%	0.057%	0.054%	0.055%
Pre	0.724%	0.067%	0.036%	0.052%	0.043%	0.034%	0.025%
Post	1.899%	0.090%	0.048%	0.069%	0.051%	0.071%	0.069%
March 19							
Day	-1.144%	0.073%	0.047%	0.035%	0.025%	0.031%	0.023%
Morning	-0.690%	0.092%	0.058%	0.067%	0.052%	0.061%	0.062%
Pre	0.078%	0.056%	0.036%	0.037%	0.035%	0.032%	0.028%
Post	-0.537%	0.044%	0.031%	0.043%	0.015%	0.029%	0.022%

Return Response to Trade Impulse - Cross-Listed Stocks							
		Average Return CIRFs					
March 18	Midpoint % Change	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	2.133%	0.089%	0.042%	0.039%	0.043%	0.035%	0.044%
Morning	-0.782%	0.086%	0.042%	0.054%	0.054%	0.046%	0.046%
Pre	0.686%	0.068%	0.034%	0.056%	0.043%	0.031%	0.021%
Post	2.244%	0.086%	0.039%	0.070%	0.044%	0.067%	0.060%
March 19							
Day	-0.741%	0.066%	0.039%	0.033%	0.026%	0.042%	0.028%
Morning	-0.417%	0.084%	0.048%	0.060%	0.053%	0.052%	0.062%
Pre	0.344%	0.047%	0.031%	0.032%	0.028%	0.029%	0.029%
Post	-0.667%	0.039%	0.026%	0.047%	0.015%	0.027%	0.018%

Return Response to Trade Impulse - Non-Cross-Listed Stocks							
		Average Return CIRFs					
March 18	Midpoint % Change	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	1.319%	0.089%	0.064%	0.048%	0.034%	0.027%	0.033%
Morning	-0.849%	0.104%	0.067%	0.070%	0.060%	0.065%	0.067%
Pre	0.779%	0.065%	0.040%	0.047%	0.042%	0.038%	0.031%
Post	1.411%	0.095%	0.062%	0.068%	0.060%	0.078%	0.082%
March 19							
Day	-1.713%	0.082%	0.060%	0.037%	0.024%	0.016%	0.015%
Morning	-1.075%	0.104%	0.071%	0.077%	0.050%	0.073%	0.063%
Pre	-0.297%	0.070%	0.042%	0.042%	0.044%	0.036%	0.027%
Post	-0.354%	0.050%	0.036%	0.037%	0.015%	0.031%	0.028%

The result of the regressions of the CIRFs against the *Inflection* trading variables outlined in the previous section are shown in Tables 2.10 and 2.11. Only the cross-listed and non-cross-listed subgroup results are given, as the difference in the *Inflection* trading patterns between the subgroups is large enough to produce muddied results for the complete sample when taken together. Each table includes the regression coefficients for each subperiod and data structure. The return CIRFs summarized in Table 2.9 are the dependent variables, with the following independent variables: *Int* denotes the intercept, *Inf %* is the proportion *Inflection* and immediately preceding trades, *Buy Run* is the average length of buy runs, *Sell Run* is the average length of sell runs, *% Buy Diff* is the size ratio for *Inflection* and immediately preceding buy trades and *Non-Inflection* buy trades not grouped with *Inflection* buy trades, *% Sell Diff* is the size ratio for *Inflection* and immediately preceding sell trades and *Non-Inflection* sell trades not grouped with *Inflection* sell trades, *Adj* R^2 is the adjusted R^2, and *F-Stat* is the F-statistic for the regression. The p-values are included below each coefficient and the F-statistic. The regression for the *Tradesign* data structure does not include the size ratio variables as there is no variance in those variables in the *Tradesign* data structure.

A number of interesting results stand out from Tables 2.10 and 2.11. For the most part, the cross-listed subgroup conforms to the expected results from the preceding section, with the relative size of *Inflection* and immediately preceding trades and *Non-Inflection* trades not grouped with *Inflection* trades having a negative influence on the return CIRFs. This pattern exists across all data structures and subperiods, with an interesting fluctuation of statistical significance between the buy and sell ratios – only one appears to be significant for any subperiod. This may reflect the

tides of trading activity and shifting influences embedded in the trading patterns. The buy and sell runs have the expected influence on the *Standard* and *Tradesign* return CIRFs, with increases in run length increasing the return CIRF (since the sell runs are coded as negatives the negative coefficients have a positive impact on the return CIRF). The consolidated data, however, shows the opposite effect, with increases in run lengths related to lower return CIRFs. This is also interesting because it is mirrored by the opposite coefficient signs for the frequency of *Inflection* and immediately preceding trades. The *Standard* and *Tradesign* data structures have a positive relationship between *Inflection* and immediately preceding trades frequency and the return CIRF while the *Consolidated* data structures have a negative relationship. This may be due to the *Consolidated* data structures having larger *Non-Inflection* trades not grouped with *Inflection* trades than *Inflection* and immediately preceding trades (size ratios less than one) while the *Standard* data structure has relatively larger *Inflection* and immediately preceding trades. Since these two variables interact in the OLS calculation, the net effect is negative for all data structures.

The explanatory power, or influence, of *Inflection* trading in the *Tradesign* data structure is less than that of the *Standard* data structure, which was expected since the *Tradesign* data structure removes the influence of relative trade size. There is a large degree of variation across the different subperiods and data structures, but the explanatory power of *Inflection* and immediately preceding trades is surprisingly high in some cases. Increases in the time used in the *Consolidated* data structures (moving from *1 Min* to *5 Min*) reduces the impact of *Inflection* trading on the return CIRFs, but this may be a reflection of the lower return CIRFs for longer time aggregation (i.e. *5 Min* return CIRFs are lower than *1 Min* return CIRFs). *Inflection* trading appears to be less influential for the non-cross-listed stocks. There is a definite drop in the statistical relationship (possibly due to fewer observations in the non-cross-listed subgroup, with 34 stocks instead of 48). The *Consolidated* data structures display a similar pattern as the cross-listed stocks, with a lower level of statistical significance, but the lack of statistical significance makes it difficult to draw comparisons for the *Standard* and *Tradesign* data structures. The difference between subgroups could be explored more fully, as the cross-listed stocks may be including

effects from the other market, such as inter-market arbitrage and market movements from US markets. Overall, however, the results are broadly in line with the expected impact of the *Inflection* trading activity. The next section discusses some robustness checks on the results.

Table 2.10: Regression Results for Cross-Listed Stocks

The table below reports the coefficients, p-values, adjusted R^2, and F-statistics for the linear regression of eq. 2.5 using return CIRFs as the dependent variable, for the cross-listed subgroup. Each panel presents the regression results for a specific data structure, broken down by subperiod. *Int* = Intercept, *Inf %* = proportion of *Inflection* and immediately preceding trades, *Buy Run* = average length of buy trade sequences, *Sell Run* = average length of sell trade sequences, *% Buy Diff* = size ratio of *Inflection* and immediately preceding buy trades to *Non-Inflection* buy trades not grouped with Inflection buy trades, *% Sell Diff* = size ratio of *Inflection* and immediately preceding sell trades to *Non-Inflection* sell trades not grouped with *Inflection* sell trades, *Adj* R^2 = adjusted R^2, and *F-Stat* = the F-Statistic. The *Tradesign* data structure does not include *% Buy Diff* and *% Sell Diff* results as there is no volume data in the *Tradesign* data structure to produce these independent variables.

Standard Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-3.0E-02	3.6E-02	2.1E-03	-2.1E-03	1.1E-03	-1.6E-03	0.61	15.50
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*
Morning	-1.8E-02	2.3E-02	1.2E-03	-1.1E-03	2.2E-04	5.9E-05	0.06	1.58
p-value	*0.11*	*0.08*	*0.10*	*0.19*	*0.17*	*0.92*		*0.19*
Pre	-2.0E-02	2.4E-02	1.3E-03	-1.3E-03	4.5E-04	-1.7E-04	0.77	32.22
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.16*		*0.00*
Post	-5.1E-03	1.0E-02	4.2E-04	-4.0E-04	2.3E-05	-1.3E-03	0.26	4.34
p-value	*0.20*	*0.03*	*0.10*	*0.29*	*0.94*	*0.01*		*0.00*
March 19th								
Day	-3.5E-02	4.4E-02	2.4E-03	-2.3E-03	-1.1E-05	-4.4E-04	0.55	12.44
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.56*	*0.05*		*0.00*
Morning	-1.1E-02	1.6E-02	9.5E-04	-5.7E-04	-3.9E-04	-2.9E-04	0.13	2.38
p-value	*0.25*	*0.15*	*0.16*	*0.32*	*0.13*	*0.53*		*0.05*
Pre	-9.8E-03	1.3E-02	7.2E-04	-5.7E-04	-2.4E-06	-1.1E-04	0.17	2.98
p-value	*0.04*	*0.01*	*0.03*	*0.10*	*0.55*	*0.13*		*0.02*
Post	-2.6E-03	4.3E-03	2.0E-04	-1.9E-04	-6.7E-05	-1.9E-04	0.23	3.76
p-value	*0.09*	*0.01*	*0.05*	*0.08*	*0.08*	*0.08*		*0.01*

Tradesign Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-2.5E-03	3.3E-03	1.9E-04	-1.8E-04			0.03	1.56
p-value	*0.13*	*0.06*	*0.09*	*0.15*				*0.21*
Morning	-4.6E-04	1.2E-03	6.7E-05	-3.0E-05			-0.03	0.52
p-value	*0.83*	*0.64*	*0.64*	*0.85*				*0.67*
Pre	-3.7E-03	4.5E-03	3.0E-04	-2.6E-04			0.25	6.31
p-value	*0.00*	*0.00*	*0.00*	*0.00*				*0.00*
Post	-7.8E-04	1.3E-03	4.2E-05	-1.3E-04			0.03	1.45
p-value	*0.26*	*0.10*	*0.33*	*0.06*				*0.24*

March 19th								
Day	-4.3E-03	5.9E-03	2.8E-04	-2.8E-04			0.13	3.38
p-value	*0.08*	*0.03*	*0.10*	*0.10*				*0.03*
Morning	-1.5E-04	1.4E-03	-2.9E-05	-2.2E-05			0.03	1.42
p-value	*0.95*	*0.65*	*0.88*	*0.89*				*0.25*
Pre	-1.1E-03	1.8E-03	1.1E-04	-6.8E-05			-0.01	0.77
p-value	*0.54*	*0.39*	*0.40*	*0.62*				*0.51*
Post	-9.2E-04	1.2E-03	9.0E-05	-8.1E-05			0.08	2.39
p-value	*0.09*	*0.05*	*0.02*	*0.04*				*0.08*

1 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	4.5E-03	-4.8E-03	-8.2E-05	6.8E-04	-2.8E-04	-4.3E-04	0.44	8.28
p-value	*0.00*	*0.00*	*0.68*	*0.00*	*0.09*	*0.00*		*0.00*
Morning	8.3E-03	-1.0E-02	-7.7E-04	8.3E-04	-1.3E-04	3.6E-05	0.62	16.49
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.76*		*0.00*
Pre	1.3E-02	-1.4E-02	-1.1E-03	1.6E-03	-1.0E-04	-4.3E-04	0.78	33.74
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.10*	*0.00*		*0.00*
Post	1.3E-02	-1.6E-02	-1.0E-03	1.7E-03	1.9E-04	1.2E-04	0.65	18.66
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.57*	*0.56*		*0.00*
March 19th								
Day	8.1E-03	-8.4E-03	-9.9E-04	9.5E-04	-3.7E-05	-2.1E-05	0.52	11.14
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.09*	*0.91*		*0.00*
Morning	1.2E-02	-1.5E-02	-1.3E-03	1.3E-03	-3.3E-05	1.7E-04	0.61	15.67
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.69*	*0.40*		*0.00*
Pre	5.8E-03	-6.2E-03	-5.3E-04	7.3E-04	-6.9E-06	-1.4E-04	0.56	12.96
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.13*	*0.00*		*0.00*
Post	-8.6E-04	5.1E-04	-9.8E-05	-6.3E-04	-3.9E-05	-9.0E-05	-0.05	0.58
p-value	*0.76*	*0.88*	*0.80*	*0.19*	*0.85*	*0.85*		*0.71*

2 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	6.2E-03	-7.5E-03	-4.3E-04	5.2E-04	-4.1E-04	-1.9E-04	0.33	5.57
p-value	*0.00*	*0.00*	*0.04*	*0.01*	*0.01*	*0.07*		*0.00*
Morning	6.8E-03	-9.2E-03	-4.3E-04	5.8E-04	-8.1E-05	-7.0E-05	0.37	6.46
p-value	*0.00*	*0.00*	*0.03*	*0.00*	*0.04*	*0.51*		*0.00*
Pre	1.4E-02	-1.6E-02	-1.2E-03	1.5E-03	-4.6E-04	-1.8E-04	0.49	9.98
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*		*0.00*
Post	4.3E-03	-6.8E-03	-1.7E-04	4.4E-04	1.5E-04	-3.1E-05	0.23	3.74
p-value	*0.01*	*0.01*	*0.25*	*0.04*	*0.25*	*0.19*		*0.01*
March 19th								
Day	9.4E-03	-1.1E-02	-8.4E-04	1.1E-03	-4.8E-05	-2.1E-04	0.69	22.04
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.02*		*0.00*
Morning	1.2E-02	-1.4E-02	-1.0E-03	1.4E-03	-2.3E-04	-6.5E-05	0.33	5.56
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.25*	*0.38*		*0.00*
Pre	3.9E-03	-4.9E-03	-2.6E-04	3.7E-04	-1.3E-05	-7.7E-05	0.45	8.75
p-value	*0.00*	*0.00*	*0.09*	*0.01*	*0.01*	*0.21*		*0.00*
Post	8.9E-04	-1.5E-03	-3.7E-05	1.1E-04	1.1E-05	2.3E-04	-0.04	0.64
p-value	*0.39*	*0.27*	*0.76*	*0.37*	*0.86*	*0.18*		*0.67*

3 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	4.0E-03	-4.0E-03	-1.7E-04	6.0E-04	-9.0E-05	-2.6E-04	0.27	4.44
p-value	*0.01*	*0.02*	*0.38*	*0.00*	*0.41*	*0.05*		*0.00*
Morning	5.6E-03	-6.9E-03	-4.8E-04	4.0E-04	-7.1E-05	-3.8E-05	0.25	4.08
p-value	*0.00*	*0.00*	*0.01*	*0.02*	*0.01*	*0.74*		*0.00*
Pre	3.6E-04	-1.5E-04	8.6E-05	6.5E-05	-9.0E-06	-2.5E-05	-0.01	0.94
p-value	*0.72*	*0.90*	*0.53*	*0.64*	*0.54*	*0.28*		*0.47*
Post	1.9E-02	-2.2E-02	-1.4E-03	2.5E-03	-4.2E-04	-8.0E-05	0.42	7.68
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.09*	*0.62*		*0.00*
March 19th								
Day	1.1E-02	-1.1E-02	-9.8E-04	1.6E-03	-5.0E-06	-5.0E-04	0.00	0.99
p-value	*0.07*	*0.11*	*0.19*	*0.05*	*0.95*	*0.13*		*0.44*
Morning	8.6E-03	-9.4E-03	-6.9E-04	1.0E-03	-3.3E-05	-1.6E-05	0.04	1.40
p-value	*0.01*	*0.02*	*0.07*	*0.02*	*0.78*	*0.50*		*0.24*
Pre	-2.3E-03	1.9E-03	3.9E-04	-4.0E-04	-1.6E-07	-4.4E-06	0.28	4.66
p-value	*0.13*	*0.29*	*0.02*	*0.03*	*0.70*	*0.89*		*0.00*
Post	1.4E-03	-1.9E-03	-4.8E-05	1.3E-04	-2.3E-06	3.5E-05	-0.06	0.50
p-value	*0.13*	*0.22*	*0.50*	*0.19*	*0.83*	*0.51*		*0.78*

5 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	1.3E-02	-1.7E-02	-1.0E-03	1.2E-03	-3.8E-04	1.3E-04	0.35	5.95
p-value	*0.00*	*0.00*	*0.01*	*0.00*	*0.01*	*0.40*		*0.00*
Morning	6.7E-03	-8.9E-03	-4.6E-04	5.8E-04	-3.7E-05	-4.3E-06	0.22	3.71
p-value	*0.00*	*0.00*	*0.05*	*0.01*	*0.08*	*0.94*		*0.01*
Pre	-2.1E-04	4.3E-04	5.6E-05	-7.8E-05	-5.4E-05	-6.7E-06	0.07	1.64
p-value	*0.80*	*0.63*	*0.54*	*0.39*	*0.20*	*0.23*		*0.17*
Post	2.1E-03	-1.3E-03	-6.8E-05	5.6E-04	9.3E-05	1.8E-04	0.01	1.08
p-value	*0.06*	*0.52*	*0.61*	*0.08*	*0.69*	*0.32*		*0.39*
March 19th								
Day	1.2E-02	-1.5E-02	-1.2E-03	1.2E-03	-3.6E-05	2.9E-05	0.32	5.33
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.21*	*0.79*		*0.00*
Morning	3.0E-03	-4.3E-03	6.8E-06	2.2E-04	-1.9E-05	2.0E-05	-0.05	0.59
p-value	*0.47*	*0.40*	*0.99*	*0.58*	*0.79*	*0.68*		*0.71*
Pre	-7.0E-04	2.9E-04	1.8E-04	-2.1E-04	-1.2E-06	3.3E-06	0.01	1.13
p-value	*0.60*	*0.84*	*0.26*	*0.28*	*0.79*	*0.77*		*0.36*
Post	5.9E-04	-7.1E-04	-3.6E-05	6.8E-06	-1.4E-05	2.5E-05	-0.09	0.26
p-value	*0.25*	*0.43*	*0.37*	*0.85*	*0.57*	*0.74*		*0.93*

Table 2.11: Regression Results for Non-Cross-Listed Stocks

The table below reports the coefficients, p-values, adjusted R^2, and F-statistics for the linear regression of eq. 2.5 using return CIRFs as the dependent variable, for the non-cross-listed subgroup. Each panel presents the regression results for a specific data structure, broken down by subperiod. *Int* = Intercept, *Inf %* = proportion of *Inflection* and immediately preceding trades, *Buy Run* = average length of buy trade sequences, *Sell Run* = average length of sell trade sequences, *% Buy Diff* = size ratio of *Inflection* and immediately preceding buy trades to *Non-Inflection* buy trades not grouped with Inflection buy trades, *% Sell Diff* = size ratio of *Inflection* and immediately preceding sell trades to *Non-Inflection* sell trades not grouped with *Inflection* sell trades, *Adj* R^2 = adjusted R^2, and *F-Stat* = the F-Statistic. The *Tradesign* data structure does not include *% Buy Diff* and *% Sell Diff* results as there is no volume data in the *Tradesign* data structure to produce these independent variables.

Standard Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	5.1E-03	-4.1E-03	-2.5E-04	4.3E-04	-1.2E-05	-8.6E-05	-0.16	0.11
p-value	*0.66*	*0.74*	*0.78*	*0.66*	*0.98*	*0.86*		*0.99*
Morning	-2.1E-02	2.1E-02	1.7E-03	-1.8E-03	-1.4E-04	2.6E-04	0.04	1.30
p-value	*0.08*	*0.10*	*0.06*	*0.06*	*0.60*	*0.61*		*0.29*
Pre	2.6E-03	-2.1E-03	-1.5E-04	2.6E-04	3.2E-04	1.4E-05	0.05	1.32
p-value	*0.46*	*0.56*	*0.52*	*0.39*	*0.03*	*0.85*		*0.29*
Post	1.9E-02	-1.7E-02	-1.3E-03	1.5E-03	-7.6E-04	5.3E-06	0.04	1.27
p-value	*0.05*	*0.09*	*0.10*	*0.10*	*0.12*	*0.98*		*0.30*
March 19th								
Day	2.5E-02	-2.0E-02	-2.2E-03	2.2E-03	-6.1E-05	-3.4E-04	0.13	1.94
p-value	*0.11*	*0.17*	*0.09*	*0.09*	*0.77*	*0.19*		*0.12*
Morning	-9.1E-03	1.2E-02	7.9E-04	-6.5E-04	-3.6E-05	-1.3E-04	-0.01	0.93
p-value	*0.45*	*0.33*	*0.48*	*0.46*	*0.75*	*0.56*		*0.48*
Pre	8.2E-03	-5.7E-03	-7.6E-04	7.1E-04	9.2E-05	-2.0E-04	0.07	1.49
p-value	*0.21*	*0.36*	*0.19*	*0.20*	*0.32*	*0.20*		*0.22*
Post	3.7E-03	-2.5E-03	-3.4E-04	2.4E-04	-3.3E-05	-5.4E-05	-0.01	0.93
p-value	*0.35*	*0.54*	*0.29*	*0.43*	*0.35*	*0.46*		*0.48*

Tradesign Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-1.3E-03	2.5E-03	1.1E-04	-9.8E-05			-0.05	0.46
p-value	*0.74*	*0.54*	*0.71*	*0.78*				*0.71*
Morning	-8.2E-03	9.5E-03	6.2E-04	-6.5E-04			0.08	1.95
p-value	*0.04*	*0.03*	*0.04*	*0.04*				*0.14*
Pre	2.3E-03	-1.8E-03	-1.4E-04	1.7E-04			0.01	1.07
p-value	*0.08*	*0.20*	*0.12*	*0.13*				*0.38*
Post	8.7E-04	-2.1E-04	-6.5E-05	-4.1E-05			-0.07	0.26
p-value	*0.79*	*0.95*	*0.81*	*0.90*				*0.86*
March 19th								
Day	4.7E-04	-1.4E-04	2.2E-05	-5.0E-05			-0.09	0.12
p-value	*0.93*	*0.98*	*0.96*	*0.91*				*0.95*
Morning	-1.6E-04	5.7E-04	1.5E-04	-5.4E-05			-0.08	0.14
p-value	*0.96*	*0.86*	*0.65*	*0.83*				*0.94*
Pre	1.8E-03	-1.2E-03	-2.2E-04	1.5E-05			0.05	1.54
p-value	*0.50*	*0.63*	*0.35*	*0.95*				*0.22*
Post	-1.7E-03	1.6E-03	1.9E-04	-2.2E-04			0.12	2.52
p-value	*0.28*	*0.32*	*0.15*	*0.07*				*0.08*

1 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	3.0E-03	-4.5E-03	1.2E-05	5.7E-04	-1.1E-04	2.0E-04	0.22	2.83
p-value	*0.05*	*0.01*	*0.95*	*0.09*	*0.21*	*0.34*		*0.03*
Morning	2.2E-03	-3.4E-03	6.6E-05	2.9E-04	-8.0E-07	5.3E-05	0.05	1.32
p-value	*0.25*	*0.08*	*0.81*	*0.42*	*0.97*	*0.80*		*0.29*
Pre	2.5E-03	-3.2E-03	-1.5E-04	2.6E-04	1.7E-05	-1.2E-04	0.08	1.58
p-value	*0.01*	*0.01*	*0.05*	*0.20*	*0.76*	*0.28*		*0.20*
Post	4.6E-03	-4.5E-03	-3.7E-04	4.8E-04	-1.9E-04	-1.2E-04	0.09	1.64
p-value	*0.00*	*0.04*	*0.07*	*0.09*	*0.45*	*0.21*		*0.18*
March 19th								
Day	1.1E-03	-1.2E-03	-2.3E-04	-1.9E-04	-7.1E-05	-1.1E-04	0.33	4.26
p-value	*0.12*	*0.13*	*0.02*	*0.13*	*0.31*	*0.12*		*0.01*
Morning	4.6E-03	-7.6E-03	1.6E-04	4.0E-04	-1.6E-04	-2.0E-04	0.30	3.85
p-value	*0.02*	*0.01*	*0.61*	*0.12*	*0.04*	*0.02*		*0.01*
Pre	2.1E-03	-1.8E-03	-2.5E-04	2.1E-04	-6.2E-05	5.0E-05	0.06	1.42
p-value	*0.01*	*0.10*	*0.03*	*0.24*	*0.21*	*0.44*		*0.25*
Post	2.3E-03	-2.1E-03	-2.5E-04	2.0E-04	-2.0E-06	-8.7E-05	0.20	2.57
p-value	*0.00*	*0.03*	*0.00*	*0.02*	*0.92*	*0.04*		*0.05*

2 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	1.7E-03	-2.5E-03	1.2E-04	2.8E-04	-6.8E-05	-6.1E-05	0.16	2.21
p-value	*0.22*	*0.14*	*0.46*	*0.24*	*0.10*	*0.11*		*0.08*
Morning	4.5E-03	-6.4E-03	-9.2E-05	5.2E-04	-1.7E-05	-1.2E-04	0.24	3.08
p-value	*0.04*	*0.02*	*0.71*	*0.11*	*0.31*	*0.20*		*0.02*
Pre	1.4E-03	-1.9E-03	-5.5E-05	3.0E-09	-1.2E-04	-1.9E-05	-0.01	0.97
p-value	*0.29*	*0.32*	*0.68*	*1.00*	*0.18*	*0.56*		*0.45*
Post	4.6E-03	-4.5E-03	-3.3E-04	4.4E-04	-3.7E-04	-8.3E-06	0.05	1.35
p-value	*0.06*	*0.21*	*0.10*	*0.12*	*0.12*	*0.76*		*0.27*
March 19th								
Day	3.9E-04	-6.9E-05	-8.1E-05	-8.3E-05	-7.8E-05	-4.7E-06	0.05	1.33
p-value	*0.57*	*0.94*	*0.18*	*0.49*	*0.05*	*0.93*		*0.28*
Morning	6.0E-03	-8.3E-03	-1.2E-04	7.1E-04	-8.5E-05	-6.2E-05	0.04	1.25
p-value	*0.15*	*0.10*	*0.83*	*0.15*	*0.51*	*0.60*		*0.31*
Pre	1.5E-03	-1.5E-03	-5.8E-05	1.3E-04	-2.9E-05	-3.6E-05	-0.01	0.95
p-value	*0.05*	*0.23*	*0.23*	*0.47*	*0.53*	*0.47*		*0.46*
Post	6.0E-04	-1.3E-03	-6.2E-05	-1.1E-04	2.1E-05	-5.9E-05	-0.11	0.34
p-value	*0.81*	*0.71*	*0.77*	*0.68*	*0.78*	*0.64*		*0.88*

3 Minute Consolidated Data Structure

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	7.3E-04	-1.9E-03	2.1E-04	9.2E-05	-5.6E-05	-2.0E-05	0.18	2.45
p-value	*0.70*	*0.36*	*0.35*	*0.77*	*0.19*	*0.54*		*0.06*
Morning	8.4E-03	-1.1E-02	-4.4E-04	9.1E-04	-2.9E-05	3.9E-05	0.21	2.74
p-value	*0.01*	*0.01*	*0.21*	*0.03*	*0.26*	*0.85*		*0.04*
Pre	1.5E-03	-9.8E-04	-1.4E-04	3.0E-05	-9.9E-05	-2.7E-05	-0.06	0.61
p-value	*0.52*	*0.73*	*0.56*	*0.91*	*0.15*	*0.66*		*0.69*
Post	6.3E-03	-7.0E-03	-5.2E-04	4.4E-04	-1.4E-04	-6.8E-05	0.06	1.40
p-value	*0.02*	*0.05*	*0.04*	*0.22*	*0.61*	*0.28*		*0.25*

March 19th								
Day	1.2E-04	9.0E-04	2.4E-05	8.2E-05	-9.2E-05	-3.2E-05	-0.06	0.64
p-value	*0.93*	*0.63*	*0.83*	*0.63*	*0.27*	*0.39*		*0.67*
Morning	7.7E-03	-9.6E-03	-5.8E-04	6.7E-04	-2.0E-05	-5.6E-05	-0.05	0.69
p-value	*0.09*	*0.11*	*0.25*	*0.20*	*0.72*	*0.46*		*0.64*
Pre	6.6E-04	4.4E-04	-5.5E-05	9.5E-05	-4.7E-05	-2.2E-05	-0.01	0.93
p-value	*0.52*	*0.77*	*0.33*	*0.60*	*0.27*	*0.44*		*0.48*
Post	1.7E-04	4.1E-04	-1.6E-05	-3.7E-05	8.4E-06	-5.6E-05	-0.05	0.72
p-value	*0.78*	*0.66*	*0.71*	*0.53*	*0.79*	*0.28*		*0.61*

5 Minute Consolidated Data Structure

	Int	**Inf %**	**Buy Run**	**Sell Run**	**% Buy Diff**	**% Sell Diff**	**Adj R^2**	**F-Stat**
March 18th								
Day	4.7E-03	-6.0E-03	-2.1E-04	5.6E-04	-7.9E-05	-8.7E-05	0.22	2.87
p-value	*0.05*	*0.03*	*0.49*	*0.07*	*0.10*	*0.08*		*0.03*
Morning	1.7E-02	-2.0E-02	-1.4E-03	1.7E-03	-1.4E-05	-1.6E-04	0.19	2.53
p-value	*0.01*	*0.01*	*0.05*	*0.01*	*0.51*	*0.61*		*0.05*
Pre	1.5E-03	-9.8E-04	-9.8E-05	7.1E-05	-1.5E-04	-2.3E-05	0.08	1.54
p-value	*0.33*	*0.59*	*0.60*	*0.67*	*0.03*	*0.23*		*0.21*
Post	1.2E-03	-3.2E-03	-2.7E-04	-3.4E-04	1.3E-03	-9.8E-05	0.20	2.64
p-value	*0.30*	*0.14*	*0.19*	*0.21*	*0.00*	*0.04*		*0.04*
March 19th								
Day	1.2E-03	-1.7E-03	-1.0E-04	1.6E-05	-1.8E-05	-2.3E-05	-0.05	0.68
p-value	*0.37*	*0.39*	*0.28*	*0.91*	*0.48*	*0.83*		*0.64*
Morning	1.3E-03	-7.7E-04	2.4E-05	7.0E-05	-2.5E-05	-7.5E-05	-0.15	0.13
p-value	*0.70*	*0.88*	*0.92*	*0.83*	*0.55*	*0.68*		*0.98*
Pre	4.2E-04	-2.2E-04	-2.4E-05	-3.5E-05	-7.1E-06	-2.0E-05	-0.12	0.30
p-value	*0.64*	*0.87*	*0.47*	*0.82*	*0.56*	*0.81*		*0.91*
Post	4.3E-04	-2.7E-06	-2.8E-05	-6.0E-06	-5.5E-05	-1.2E-05	-0.08	0.53
p-value	*0.27*	*1.00*	*0.49*	*0.79*	*0.34*	*0.49*		*0.75*

2.5: Robustness

Three robustness checks have been conducted. The first uses the *Inflection* trades instead of *Inflection* and immediately preceding trades to produce *Inflection* frequency and relative size data. The regression results are presented in Table 2.12 for the *Standard* and *1 Min* data structures. The results are similar in direction and scale to the results in Tables 2.10 and 2.11, with an apparent reduction in the impact of the relative trade sizes. The difference in results compared to *Inflection* and immediately preceding trades signal the importance of the information contained in the last trade before a change in direction. The importance of the last trade of the *Inflection* and immediately preceding trades on return CIRFs suggests that the *Inflection* trade is being placed at specific points in the sequence as opposed to being random or predicting a change in direction "at some point in time". In circumstances where the stock price

changes are short-lived (i.e. reversed within the time frame of the subperiod), the informed nature of the *Inflection* trades would be taking advantage of over-reaction by uninformed traders. When the price change is not temporary, the informed traders are more likely to be taking advantage of the delayed reaction of uninformed traders.

Table 2.12: Regression Results for Return CIRFs using *Inflection* Trades

The table below reports the coefficients, p-values, adjusted R^2, and F-statistics for the linear regression of eq. 2.5 using return CIRFs as the dependent variable, but using *Inflection* trades when calculating the independent variables. Each panel presents the regression results for a specific data structure and subgroup, broken down by subperiod. Only the *Standard* and *1 Minute* data structures are presented. *Int* = Intercept, *Inf %* = proportion of *Inflection* trades, *Buy Run* = average length of buy trade sequences, *Sell Run* = average length of sell trade sequences, *% Buy Diff* = ratio of *Inflection* buy trade size to *Non-Inflection* buy trade size, *% Sell Diff* = ratio of *Inflection* sell trade size to *Non-Inflection* sell trade size, *Adj* R^2 = adjusted R^2, and *F-Stat* = the F-Statistic.

Standard data structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	2.6E-05	6.7E-03	5.0E-05	-7.7E-05	-1.1E-03	-1.6E-04	0.18	3.01
p-value	*1.00*	*0.55*	*0.92*	*0.89*	*0.04*	*0.86*		*0.02*
Morning	6.1E-03	-6.7E-03	-3.7E-04	5.6E-04	-1.3E-04	7.1E-05	-0.06	0.49
p-value	*0.57*	*0.72*	*0.60*	*0.52*	*0.54*	*0.91*		*0.78*
Pre	-1.3E-02	2.5E-02	9.7E-04	-9.0E-04	-3.2E-04	-3.5E-04	0.21	3.55
p-value	*0.04*	*0.01*	*0.02*	*0.07*	*0.18*	*0.39*		*0.01*
Post	-5.5E-03	1.6E-02	4.7E-04	-5.5E-04	-9.1E-07	-1.4E-03	0.19	3.13
p-value	*0.19*	*0.04*	*0.12*	*0.25*	*1.00*	*0.03*		*0.02*
March 19th								
Day	-3.5E-02	6.8E-02	2.4E-03	-2.3E-03	-6.5E-06	-6.5E-04	0.37	6.53
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.69*	*0.08*		*0.00*
Morning	1.5E-02	-2.3E-02	-8.6E-04	9.1E-04	-3.5E-04	-7.4E-04	0.13	2.36
p-value	*0.14*	*0.21*	*0.27*	*0.15*	*0.28*	*0.10*		*0.06*
Pre	-2.4E-03	7.2E-03	2.3E-04	-8.5E-05	-1.4E-06	-3.0E-04	0.12	2.25
p-value	*0.65*	*0.43*	*0.53*	*0.82*	*0.67*	*0.12*		*0.07*
Post	-1.9E-03	5.4E-03	1.5E-04	-1.6E-04	-4.9E-05	-2.3E-04	0.17	2.90
p-value	*0.27*	*0.07*	*0.17*	*0.17*	*0.06*	*0.19*		*0.02*

Standard data structure with Non-Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	1.6E-02	-2.3E-02	-1.1E-03	1.4E-03	1.4E-04	-3.2E-04	-0.02	0.89
p-value	*0.09*	*0.11*	*0.13*	*0.11*	*0.67*	*0.38*		*0.50*
Morning	-1.2E-03	1.3E-03	3.5E-04	-4.2E-04	-1.0E-04	-3.8E-04	-0.08	0.52
p-value	*0.92*	*0.94*	*0.70*	*0.69*	*0.69*	*0.54*		*0.76*
Pre	3.3E-03	-4.4E-03	-2.0E-04	3.6E-04	3.8E-04	2.3E-05	0.28	3.52
p-value	*0.28*	*0.37*	*0.33*	*0.21*	*0.00*	*0.72*		*0.01*
Post	2.4E-02	-3.4E-02	-1.8E-03	2.3E-03	-2.2E-04	3.5E-04	0.03	1.17
p-value	*0.04*	*0.05*	*0.05*	*0.05*	*0.65*	*0.58*		*0.35*

March 19th								
Day	2.0E-02	-2.3E-02	-1.7E-03	1.8E-03	-8.6E-05	-2.2E-04	0.08	1.57
p-value	*0.34*	*0.44*	*0.32*	*0.30*	*0.47*	*0.12*		*0.20*
Morning	-3.9E-03	1.0E-02	3.1E-04	-3.0E-04	-6.0E-05	-1.8E-04	-0.04	0.73
p-value	*0.82*	*0.70*	*0.84*	*0.82*	*0.47*	*0.22*		*0.61*
Pre	4.6E-03	-3.1E-03	-5.5E-04	4.4E-04	3.4E-05	-1.1E-04	0.02	1.14
p-value	*0.39*	*0.67*	*0.29*	*0.40*	*0.46*	*0.25*		*0.36*
Post	1.0E-03	5.3E-04	-1.3E-04	5.4E-05	-3.0E-05	-7.1E-05	0.03	1.23
p-value	*0.83*	*0.94*	*0.76*	*0.89*	*0.31*	*0.22*		*0.32*

1 Minute Consolidated Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	1.9E-02	-2.3E-02	-1.6E-03	2.0E-03	7.0E-05	-2.6E-04	0.23	3.85
p-value	*0.02*	*0.02*	*0.07*	*0.02*	*0.53*	*0.28*		*0.01*
Morning	8.7E-03	-1.1E-02	-7.0E-04	9.4E-04	-3.3E-05	3.4E-04	0.02	1.20
p-value	*0.15*	*0.16*	*0.26*	*0.10*	*0.55*	*0.44*		*0.32*
Pre	3.8E-04	-2.7E-04	2.3E-04	2.2E-04	2.6E-04	-9.0E-05	0.22	3.59
p-value	*0.98*	*0.98*	*0.87*	*0.88*	*0.00*	*0.64*		*0.01*
Post	1.1E-02	-9.6E-03	-5.9E-04	1.8E-03	-1.2E-04	-6.3E-04	0.05	1.50
p-value	*0.25*	*0.37*	*0.54*	*0.11*	*0.76*	*0.13*		*0.21*
March 19th								
Day	-2.5E-02	2.8E-02	2.8E-03	-3.0E-03	-5.0E-06	2.4E-05	-0.06	0.44
p-value	*0.26*	*0.28*	*0.26*	*0.23*	*0.85*	*0.95*		*0.82*
Morning	2.8E-02	-3.3E-02	-2.8E-03	2.9E-03	4.9E-05	-1.9E-04	0.13	2.35
p-value	*0.00*	*0.00*	*0.01*	*0.01*	*0.84*	*0.68*		*0.06*
Pre	-1.5E-02	1.7E-02	1.8E-03	-1.7E-03	-1.9E-06	1.3E-04	0.22	3.67
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.66*	*0.44*		*0.01*
Post	2.6E-03	-3.7E-03	-4.1E-04	-2.7E-04	-5.7E-05	-1.1E-04	-0.04	0.63
p-value	*0.84*	*0.80*	*0.73*	*0.85*	*0.62*	*0.85*		*0.68*

1 Minute Consolidated Data Structure with Non-Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	2.0E-02	-2.7E-02	-1.6E-03	2.1E-03	1.8E-04	2.4E-04	0.08	1.61
p-value	*0.05*	*0.05*	*0.09*	*0.05*	*0.19*	*0.21*		*0.19*
Morning	-1.2E-02	1.4E-02	1.5E-03	-1.2E-03	5.5E-05	1.2E-04	0.03	1.20
p-value	*0.17*	*0.19*	*0.09*	*0.22*	*0.32*	*0.50*		*0.33*
Pre	2.2E-03	-2.7E-03	-1.2E-04	1.2E-04	6.7E-05	-5.0E-05	-0.08	0.50
p-value	*0.42*	*0.50*	*0.58*	*0.67*	*0.31*	*0.48*		*0.77*
Post	1.6E-03	3.6E-04	-1.8E-04	3.5E-04	2.3E-04	-6.5E-05	-0.09	0.45
p-value	*0.70*	*0.95*	*0.66*	*0.47*	*0.53*	*0.74*		*0.81*
March 19th								
Day	-5.7E-04	9.4E-04	-1.1E-04	-4.1E-04	-5.6E-05	-6.7E-05	0.29	3.67
p-value	*0.87*	*0.84*	*0.70*	*0.27*	*0.24*	*0.22*		*0.01*
Morning	7.4E-03	-1.1E-02	-1.3E-04	5.4E-04	-7.8E-05	-1.0E-04	0.04	1.29
p-value	*0.43*	*0.39*	*0.88*	*0.51*	*0.24*	*0.30*		*0.30*
Pre	-1.1E-03	3.0E-03	3.6E-05	-1.1E-04	-2.2E-05	-4.7E-05	-0.03	0.81
p-value	*0.70*	*0.41*	*0.88*	*0.75*	*0.37*	*0.58*		*0.55*
Post	1.3E-03	-7.1E-04	-1.5E-04	8.8E-05	4.4E-06	-1.7E-05	-0.03	0.82
p-value	*0.40*	*0.73*	*0.30*	*0.53*	*0.81*	*0.68*		*0.55*

Although the determination of the return CIRFs across data structures is the focus of this Chapter, this section reports further analysis of the drivers of the return CIRFs. Regressions of midpoint

price changes and the *Inflection* and immediately preceding trades data were conducted to determine if there is a significant relationship between the midpoint price change and *Inflection* and immediately preceding trades, which could indicate the presence of confounding influences in the return CIRFs. Table 2.13 presents the results of the regression of midpoint prices against the *Inflection* and immediately preceding trades variables. For the most part there is no significant relationship, but where there is a statistically significant relationship (e.g. Morning on March 18th for the *Standard* data structure) there is no relationship between *Inflection* trading activity and the return CIRFs. This may signal that there is some information content from *Inflection* trading that relates to price changes, another potential avenue for further exploration.

Table 2.13: Regression Results for Midpoint Price Change (%)

The table below reports the coefficients, p-values, adjusted R^2, and F-statistics for the linear regression of eq. 2.5, but using the Midpoint return instead of the CIRF as the dependent variable. Each panel presents the regression results for a specific data structure and subgroup, broken down by subperiod. Only the *Standard* and *1 Minute* data structures are presented. *Int* = Intercept, *Inf %* = proportion of *Inflection* and immediately preceding trades, *Buy Run* = average length of buy trade sequences, *Sell Run* = average length of sell trade sequences, *% Buy Diff* = size ratio of *Inflection* and immediately preceding buy trades to *Non-Inflection* buy trades not grouped with Inflection buy trades, *% Sell Diff* = size ratio of *Inflection* and immediately preceding sell trades to *Non-Inflection* sell trades not grouped with *Inflection* sell trades, *Adj* R^2 = adjusted R^2, and *F-Stat* = the F-Statistic.

Standard Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-3.3E-01	2.9E-01	2.8E-02	-2.9E-02	1.6E-02	-9.3E-03	0.00	1.04
p-value	*0.37*	*0.46*	*0.28*	*0.33*	*0.23*	*0.68*		*0.41*
Morning	-1.0E-01	1.1E-01	1.1E-02	1.2E-03	2.1E-03	4.3E-03	0.22	3.62
p-value	*0.48*	*0.50*	*0.27*	*0.91*	*0.31*	*0.55*		*0.01*
Pre	-5.9E-02	5.2E-02	6.6E-03	-6.6E-03	-2.4E-03	-2.4E-04	0.10	2.05
p-value	*0.35*	*0.46*	*0.17*	*0.17*	*0.16*	*0.92*		*0.09*
Post	-2.2E-04	-4.5E-02	-4.0E-04	-1.8E-03	4.3E-02	-1.3E-02	0.22	3.64
p-value	*1.00*	*0.80*	*0.97*	*0.90*	*0.00*	*0.50*		*0.01*
March 19th								
Day	-3.3E-01	3.6E-01	2.4E-02	-2.0E-02	-1.7E-03	7.1E-03	-0.04	0.68
p-value	*0.38*	*0.41*	*0.35*	*0.46*	*0.14*	*0.58*		*0.64*
Morning	-4.7E-01	5.4E-01	3.8E-02	-2.3E-02	4.6E-03	4.4E-03	0.06	1.59
p-value	*0.05*	*0.05*	*0.03*	*0.10*	*0.48*	*0.70*		*0.18*
Pre	-2.0E-01	2.1E-01	1.5E-02	-1.5E-02	-9.0E-05	-1.3E-03	0.09	1.99
p-value	*0.02*	*0.03*	*0.01*	*0.02*	*0.21*	*0.30*		*0.10*
Post	-1.9E-02	3.2E-02	-1.7E-04	-6.7E-04	7.5E-04	-3.6E-03	-0.02	0.80
p-value	*0.75*	*0.62*	*0.97*	*0.87*	*0.61*	*0.38*		*0.55*

Standard Data Structure with Non-Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	5.1E-01	-5.9E-01	-3.4E-02	3.5E-02	4.6E-03	1.4E-02	0.20	2.67
p-value	*0.03*	*0.02*	*0.05*	*0.07*	*0.59*	*0.14*		*0.04*
Morning	2.1E-01	-2.9E-01	-1.2E-02	1.0E-02	-4.5E-03	5.8E-03	0.16	2.26
p-value	*0.26*	*0.15*	*0.38*	*0.50*	*0.31*	*0.46*		*0.08*
Pre	9.1E-02	-9.7E-02	-4.9E-03	5.6E-03	2.2E-04	-2.6E-04	0.00	0.97
p-value	*0.05*	*0.05*	*0.12*	*0.17*	*0.90*	*0.78*		*0.45*
Post	-1.4E-01	1.4E-01	1.1E-02	-1.4E-02	8.8E-03	-3.8E-03	-0.09	0.46
p-value	*0.43*	*0.42*	*0.44*	*0.38*	*0.33*	*0.39*		*0.80*
March 19th								
Day	-3.2E-02	3.7E-02	2.5E-03	4.7E-03	2.7E-03	-2.5E-03	-0.15	0.15
p-value	*0.96*	*0.95*	*0.96*	*0.93*	*0.75*	*0.81*		*0.98*
Morning	1.0E-01	-1.5E-01	1.9E-03	1.2E-02	-2.6E-03	3.7E-03	-0.03	0.78
p-value	*0.70*	*0.58*	*0.94*	*0.55*	*0.31*	*0.44*		*0.57*
Pre	-6.4E-02	5.4E-02	7.5E-03	-3.4E-03	7.6E-04	-8.0E-04	-0.04	0.72
p-value	*0.38*	*0.44*	*0.24*	*0.58*	*0.46*	*0.64*		*0.61*
Post	3.6E-02	-2.8E-02	-1.7E-03	5.8E-03	-3.2E-04	-2.6E-03	-0.06	0.61
p-value	*0.75*	*0.82*	*0.86*	*0.50*	*0.76*	*0.23*		*0.69*

1 Minute Consolidated Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-8.2E-02	9.2E-02	1.1E-02	-1.1E-03	1.6E-02	2.6E-02	-0.02	0.80
p-value	*0.54*	*0.40*	*0.61*	*0.96*	*0.37*	*0.09*		*0.56*
Morning	1.9E-02	-6.0E-02	2.2E-03	7.1E-03	-2.3E-05	5.7E-03	0.39	6.98
p-value	*0.42*	*0.03*	*0.53*	*0.06*	*0.98*	*0.04*		*0.00*
Pre	-1.5E-02	8.3E-03	4.0E-03	-3.3E-03	-5.3E-04	2.4E-03	-0.01	0.88
p-value	*0.53*	*0.72*	*0.32*	*0.43*	*0.62*	*0.22*		*0.50*
Post	-7.2E-02	8.8E-02	-9.6E-04	-1.1E-02	7.1E-03	3.2E-02	0.20	3.34
p-value	*0.33*	*0.28*	*0.93*	*0.43*	*0.64*	*0.00*		*0.01*
March 19th								
Day	-4.5E-02	-6.6E-02	2.7E-02	6.8E-03	-3.2E-03	2.9E-02	0.16	2.79
p-value	*0.66*	*0.40*	*0.14*	*0.71*	*0.03*	*0.03*		*0.03*
Morning	-6.2E-02	2.7E-02	2.4E-02	5.3E-03	2.0E-03	6.9E-03	0.16	2.86
p-value	*0.29*	*0.65*	*0.02*	*0.55*	*0.47*	*0.31*		*0.03*
Pre	3.2E-02	-2.6E-02	-2.7E-03	5.3E-03	-1.8E-04	-2.7E-04	-0.05	0.58
p-value	*0.26*	*0.33*	*0.52*	*0.25*	*0.20*	*0.84*		*0.72*
Post	2.6E-02	-4.1E-02	-6.2E-04	5.8E-03	8.1E-04	-2.6E-03	-0.02	0.84
p-value	*0.26*	*0.15*	*0.85*	*0.14*	*0.64*	*0.52*		*0.53*

1 Minute Consolidated Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-3.0E-02	2.9E-02	9.2E-03	-2.1E-03	9.3E-04	2.2E-03	-0.07	0.59
p-value	*0.56*	*0.59*	*0.18*	*0.86*	*0.76*	*0.76*		*0.71*
Morning	-5.8E-02	-1.5E-02	1.6E-02	-2.8E-03	5.7E-04	3.1E-03	0.23	2.98
p-value	*0.17*	*0.73*	*0.01*	*0.73*	*0.20*	*0.50*		*0.03*
Pre	-2.0E-03	1.8E-02	8.6E-04	-9.6E-04	-2.3E-04	2.0E-04	-0.14	0.19
p-value	*0.91*	*0.43*	*0.55*	*0.80*	*0.82*	*0.92*		*0.96*
Post	4.3E-03	1.2E-01	-2.7E-03	8.6E-03	-4.5E-03	-1.9E-04	0.18	2.41
p-value	*0.89*	*0.02*	*0.55*	*0.18*	*0.42*	*0.92*		*0.06*

March 19th								
Day	9.9E-03	-5.3E-02	-1.3E-03	6.5E-03	4.7E-03	1.6E-03	-0.11	0.36
p-value	*0.87*	*0.47*	*0.87*	*0.57*	*0.46*	*0.79*		*0.87*
Morning	7.6E-03	-1.6E-02	1.1E-03	6.3E-03	-1.0E-03	2.2E-03	-0.03	0.81
p-value	*0.87*	*0.80*	*0.88*	*0.30*	*0.55*	*0.24*		*0.55*
Pre	-3.6E-03	-2.2E-02	6.7E-04	-1.6E-03	4.1E-04	5.2E-04	0.01	1.04
p-value	*0.73*	*0.16*	*0.69*	*0.53*	*0.56*	*0.57*		*0.41*
Post	3.9E-02	-7.1E-02	-2.2E-03	4.7E-03	-1.5E-04	-1.7E-03	0.07	1.46
p-value	*0.13*	*0.05*	*0.44*	*0.12*	*0.85*	*0.26*		*0.23*

The final robustness check replaces the return CIRFs in response to a trade impulse with the trade CIRF response to the same trade impulse. The trade CIRF has a more direct relationship to the trade impulse (i.e. auto-correlation instead of a cross-correlation), with the same expected outcomes from *Inflection* trading activity. As shown in Table 2.14 the influence of *Inflection* and immediately preceding trades on the trade CIRFs is stronger than for the return CIRFs. This influence seems to be exerted largely through the relative size of the *Inflection* and immediately preceding trades and extends to the non-cross-listed stocks to a greater degree. Although not discussed in the preceding sections, this result may indicate a knock-on effect for *Inflection* and immediately preceding trades on the return CIRFs. Since the trade CIRF feeds into the return CIRF by estimating trades triggered by the initial trade impulse, a systematically lower trade CIRF would underestimate the follow-on trading activity and therefore the return CIRF.

Table 2.14: Regression Results for Trade CIRFs

The table below reports the coefficients, p-values, adjusted R^2, and F-statistics for the linear regression of eq. 2.5 using trade CIRFs as the dependent variable. Each panel presents the regression results for a specific data structure and subgroup, broken down by subperiod. Only the *Standard* and *1 Minute* data structures are presented. *Int* = Intercept, *Inf %* = proportion of *Inflection* and immediately preceding trades, *Buy Run* = average length of buy trade sequences, *Sell Run* = average length of sell trade sequences, *% Buy Diff* = size ratio of *Inflection* and immediately preceding buy trades to *Non-Inflection* buy trades not grouped with Inflection buy trades, *% Sell Diff* = size ratio of *Inflection* and immediately preceding sell trades to *Non-Inflection* sell trades not grouped with *Inflection* sell trades, *Adj* R^2 = adjusted R^2, and *F-Stat* = the F-Statistic.

Standard Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	4.8E+03	-3.8E+03	-4.7E+01	-2.7E+01	-2.3E+02	-6.8E+02	0.54	11.86
p-value	*0.03*	*0.11*	*0.77*	*0.88*	*0.01*	*0.00*		*0.00*
Morning	4.6E+03	-4.9E+03	-5.5E-01	4.3E+01	-7.9E+01	-3.5E+02	0.48	9.83
p-value	*0.16*	*0.20*	*1.00*	*0.86*	*0.09*	*0.04*		*0.00*
Pre	1.7E+03	-1.0E+03	4.0E+01	-6.9E+01	-5.1E+01	-1.2E+02	0.31	5.31
p-value	*0.24*	*0.53*	*0.71*	*0.52*	*0.19*	*0.03*		*0.00*
Post	6.4E+03	-5.5E+03	-2.1E+02	2.1E+02	-1.9E+02	-4.2E+02	0.36	6.40
p-value	*0.00*	*0.00*	*0.02*	*0.12*	*0.09*	*0.01*		*0.00*
March 19th								
Day	2.3E+03	-2.0E+03	2.0E+02	-5.7E+00	-3.6E+01	-2.8E+02	0.32	5.32
p-value	*0.57*	*0.66*	*0.45*	*0.98*	*0.00*	*0.04*		*0.00*
Morning	6.8E+02	8.9E+01	3.0E+02	-8.8E+01	-1.4E+02	-1.4E+02	0.31	5.15
p-value	*0.81*	*0.98*	*0.16*	*0.62*	*0.08*	*0.32*		*0.00*
Pre	-2.0E+03	3.3E+03	3.8E+02	-2.2E+02	-4.2E+00	-1.3E+02	0.24	4.01
p-value	*0.53*	*0.35*	*0.09*	*0.37*	*0.12*	*0.01*		*0.00*
Post	1.9E+03	-1.3E+03	4.5E+00	-1.7E+02	-4.6E+01	-3.3E+02	0.38	6.79
p-value	*0.28*	*0.52*	*0.97*	*0.19*	*0.31*	*0.01*		*0.00*

Standard Data Structure with Non-Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	6.5E+03	-6.1E+03	-3.0E+02	2.4E+02	-3.5E+01	-9.3E+01	0.09	1.62
p-value	*0.15*	*0.20*	*0.37*	*0.53*	*0.84*	*0.61*		*0.19*
Morning	8.9E+03	-9.0E+03	-4.5E+02	3.8E+02	-9.3E+01	-6.8E+01	0.28	3.62
p-value	*0.01*	*0.02*	*0.08*	*0.17*	*0.25*	*0.64*		*0.01*
Pre	2.6E+03	-1.8E+03	-1.7E+01	2.7E+01	-9.6E+01	-5.6E+01	0.17	2.39
p-value	*0.09*	*0.26*	*0.87*	*0.84*	*0.11*	*0.08*		*0.06*
Post	5.9E+03	-5.8E+03	-2.3E+02	2.4E+02	3.5E+00	-3.0E+01	0.16	2.29
p-value	*0.13*	*0.14*	*0.46*	*0.50*	*0.99*	*0.76*		*0.07*
March 19th								
Day	1.6E+04	-1.4E+04	-1.2E+03	1.0E+03	-4.8E+01	-1.9E+02	0.23	2.95
p-value	*0.02*	*0.03*	*0.03*	*0.06*	*0.59*	*0.09*		*0.03*
Morning	5.6E+03	-5.2E+03	-3.0E+02	1.3E+02	-1.6E+00	-1.2E+02	0.03	1.20
p-value	*0.45*	*0.47*	*0.67*	*0.81*	*0.98*	*0.36*		*0.33*
Pre	-7.9E+02	1.6E+03	1.6E+02	-2.3E+02	6.0E+00	-4.5E+01	0.32	4.05
p-value	*0.45*	*0.11*	*0.08*	*0.01*	*0.68*	*0.07*		*0.01*
Post	3.2E+03	-1.8E+03	-2.1E+02	5.2E+01	-3.9E+01	-2.5E+01	-0.05	0.69
p-value	*0.41*	*0.64*	*0.50*	*0.86*	*0.26*	*0.73*		*0.63*

1 Minute Consolidated Data Structure with Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	-1.6E+03	1.7E+03	1.0E+03	-3.4E+02	-6.8E+01	-8.9E+02	0.25	4.05
p-value	*0.49*	*0.38*	*0.01*	*0.36*	*0.82*	*0.00*		*0.00*
Morning	5.6E+02	8.7E+00	1.1E+02	-2.6E+02	-5.7E+01	-7.3E+01	0.18	3.01
p-value	*0.38*	*0.99*	*0.27*	*0.01*	*0.02*	*0.33*		*0.02*
Pre	4.1E+03	-3.1E+03	-1.9E+02	4.9E+02	-1.5E+02	-6.9E+00	0.27	4.50
p-value	*0.00*	*0.00*	*0.20*	*0.00*	*0.00*	*0.92*		*0.00*
Post	-1.1E+03	1.7E+03	9.6E+02	2.1E+02	-1.3E+02	-1.3E+02	0.23	3.80
p-value	*0.59*	*0.45*	*0.00*	*0.59*	*0.75*	*0.61*		*0.01*
March 19th								
Day	8.9E+03	-2.4E+03	-1.0E+03	1.6E+03	1.9E+01	-7.8E+02	0.00	0.96
p-value	*0.05*	*0.49*	*0.19*	*0.06*	*0.76*	*0.17*		*0.45*
Morning	-1.1E+03	1.9E+03	6.2E+02	-1.4E+02	-5.6E+01	6.3E+01	0.12	2.31
p-value	*0.39*	*0.14*	*0.01*	*0.45*	*0.36*	*0.67*		*0.06*
Pre	-2.1E+02	1.1E+03	2.2E+02	-1.9E+02	2.5E+00	-2.1E+01	0.05	1.52
p-value	*0.77*	*0.09*	*0.04*	*0.10*	*0.48*	*0.52*		*0.21*
Post	-3.1E+04	3.4E+04	3.3E+03	-9.3E+03	-4.5E+02	-4.0E+03	-0.09	0.21
p-value	*0.59*	*0.63*	*0.68*	*0.35*	*0.92*	*0.69*		*0.95*

1 Minute Consolidated Data Structure with Non-Cross-Listed Stocks

	Int	Inf %	Buy Run	Sell Run	% Buy Diff	% Sell Diff	Adj R^2	F-Stat
March 18th								
Day	1.7E+03	1.6E+02	6.6E+01	2.7E+02	-1.3E+01	-3.5E-01	-0.07	0.56
p-value	*0.19*	*0.90*	*0.69*	*0.36*	*0.87*	*1.00*		*0.73*
Morning	4.4E+02	5.8E+02	1.4E+02	-1.7E+02	-1.0E+01	-1.1E+02	0.16	2.25
p-value	*0.50*	*0.37*	*0.13*	*0.18*	*0.13*	*0.11*		*0.08*
Pre	9.4E+02	-5.7E+02	2.9E+00	-2.4E+02	-2.8E+01	-4.0E+01	0.00	1.00
p-value	*0.28*	*0.62*	*0.97*	*0.22*	*0.59*	*0.70*		*0.44*
Post	2.3E+03	-1.2E+03	3.3E+02	4.0E+02	-4.1E+02	-1.1E+02	0.13	1.96
p-value	*0.18*	*0.62*	*0.17*	*0.24*	*0.17*	*0.30*		*0.12*
March 19th								
Day	-7.2E+01	1.8E+02	4.1E+01	-4.8E+02	-5.7E+01	1.8E+01	0.56	9.29
p-value	*0.88*	*0.75*	*0.51*	*0.00*	*0.24*	*0.70*		*0.00*
Morning	1.4E+03	-2.2E+02	-2.5E+00	4.5E+01	-1.7E-01	-3.4E+00	-0.17	0.05
p-value	*0.06*	*0.82*	*0.98*	*0.65*	*1.00*	*0.91*		*1.00*
Pre	-2.2E+02	2.1E+02	3.7E+02	-1.9E+02	1.7E+01	-7.6E+01	0.55	9.20
p-value	*0.56*	*0.70*	*0.00*	*0.04*	*0.52*	*0.03*		*0.00*
Post	-8.2E+03	3.4E+04	1.1E+02	-1.4E+02	-8.0E+01	3.7E+02	-0.10	0.38
p-value	*0.81*	*0.46*	*0.98*	*0.97*	*0.94*	*0.86*		*0.86*

2.6: Conclusions

The regression results in this Chapter add to the information impounding literature by showing that an identifiable trading pattern related to *Inflection* and immediately preceding trades affects the return CIRFs and therefore our understanding of information flow into stock prices. This

points to a problem with the information measure caused by the VAR model's susceptibility to patterns in the trading data. As these trading patterns do not relate to changes in midpoint prices, they point to a measurement issue and not a matter of a missing confounding variable in the VAR model. The trading pattern variables used in this Chapter contribute to the literature by indicating additional variables that can be included in the VAR model to help incorporate trading pattern effects into the return CIRFs. A unique hidden effect, the underestimation of the trade CIRFs, has also been found. The results suggest that the VAR model measures trading smoothness, which does not necessarily correlate with price movement. As information is traditionally viewed as only transmitting through active trading, this presents a problem for the VAR model as a measurement tool for information flow. Although trading activity may impound information into stock prices, the VAR model is measuring the pattern of this trading activity, not its effect. Non-volatile trading activity with little price change could measure a large amount of information flow, while volatile stock trading with a large price change suggests that uninformed liquidity trading caused the price change. If the information impounding process in a market is not governed by consensus and a lack of volatility, but by a conflict of diverse opinions revealing information, information models will need to incorporate the causes of volatile trading that are currently absent from existing models.

Maybe it is a philosophical question about what we mean by information flow. It may be that we are applying a single method to measure different types of information; instead of thinking of different trading patterns as affecting a single measure of information, perhaps the different trading patterns are transmitting different information or are part of different price discovery processes.

2.7: Extensions

One blind spot not covered in this Chapter is the nature of the raw data. Only two series are included, one for trades and one for returns. The return series, however, is really an output and not a directly measurable variable. Returns arise from changes in midpoints that are defined by

the bid and ask prices. The bid and ask prices, in turn, change as a result of trades, both active and passive. Only the active trades are included in the data in this Chapter, and most microstructure literature. There is a lack of return impulses in the microstructure literature, perhaps because of the nature of returns – it is not possible for a trader to execute a return, only a trade. Returns, however, are influential on both return and trade CIRFs.

The return CIRF results in Table 2.9 assume the impulse was a trade. If the impulse was a return instead, there would be a frame of reference for the return CIRF caused by a trade impulse as it would be possible to compare the relative influence of trade and return impulses on trade and return CIRFs. As it stands, only using a trade impulse for the return CIRF tacitly assumes that only trades impact returns and trades. Instead of assuming a set size for the return used as an impulse, the following table is based on finding the return that produces the same return CIRFs as the trade impulses used in Table 2.9. The derived return's probability in each stock's return empirical cumulative density function (ECDF) is then compared to the trade impulse's probability in each stock's trade ECDF as a returns version of the trade percentile analysis presented in Hasbrouck (1991a). If a particular return size causes the same impact as a particular trade size but is more likely to occur, the return impact could be considered greater than the trade impact.

Table 2.15: ECDF Percentile of Return Impulse

This table reports the average percentile of the returns that create the same return CIRF as the trade impulses used in each data structure. For example, if a 1,000 share trade impulse in the Standard data structure on March 18th creates a return CIRF of 0.08%, we can calculate the return shock that produces the same return CIRF of 0.08% and the percentile of that calculated return in the return dataset. For example, the return impulses that produce the same return CIRFs as the trade impulses for the Standard data structure on March 18th are, on average, at the 89th percentile of the corresponding return observations (i.e. only 11% of the return observations are larger than the calculated return impulses).

	Standard	Tradesign	1 Minute	2 Minute	3 Minute	5 Minute
March 18th	0.89	0.90	0.24	0.15	0.12	0.09
March 19th	0.86	0.90	0.21	0.15	0.10	0.09

Table 2.16: ECDF Percentile of Trade Impulse

This table reports the average percentile of the trade impulses used to produce the return CIRFs for each data structure. The absolute value of the trades is used for the calculation such that buy and sell trades are both signed positively. For example, a 1,000 share trade is, on average, at the 97th percentile of all trades in the *Standard* data

structure on March 18th (i.e. only 3% of the trade observations are larger than 1,000 shares). The *Tradesign* data structure does not have trade volumes, all trade indicators have an absolute value of 1.

	Standard	Tradesign	1 Minute	2 Minute	3 Minute	5 Minute
March 18th	0.97	1.00	0.61	0.48	0.40	0.31
March 19th	0.96	1.00	0.61	0.48	0.40	0.31

As illustrated in Tables 2.15 and 2.16, it is more likely that a return will occur that has the same impact on returns as the trade impulse used in the return CIRFs. Since these returns can be triggered by passive order flow, it stands to reason that passive order flow can have a meaningful impact on price changes. A slightly different argument exists for the *Consolidated* data sets. The assumption is that trades cause returns, but not the opposite, which preferences trades as an explanatory variable for returns. What happens if we reverse this assumption, and assume that returns cause trades? Tables 2.17 and 2.18 illustrate the change in adjusted R^2 for VAR models based on these differing assumptions. Table 2.17 shows the adjusted R^2 for the return CIRFs comparing the returns cause trades assumption with the reverse when the impulse is a 1,000 share trade. The explanatory power of a trade impulse is significantly lower for the returns cause trades assumption (the first four columns in Table 2.17) compared to the trades cause returns assumption (the last four columns in Table 2.17). The measurement of the trade impulse price impact is dependent on the assumption that trades cause returns, if this assumption is not correct then any conclusions drawn are similarly incorrect.

Table 2.17: Adjusted R^2 for Return as Dependent Variable

This table reports the average adjusted R^2 for return CIRFs resulting from 1,000 share trade impulses in each Consolidated data structure, for returns cause trades and trades cause returns assumptions. The first four columns of the table present the adjusted R^2 of return CIRFs for each Consolidated data structure when returns are assumed to cause trades, but not the opposite. The last four columns in the table present the adjusted R^2 of return CIRFs for each Consolidated data structure when trades are assumed to cause returns, but not the reverse.

	Adj R^2 (Returns cause Trades)				**Adj R^2 (Trades Cause Returns)**			
March 18th	1 Min	2 Min	3 Min	5 Min	1 Min	2 Min	3 Min	5 Min
Day	0.04	0.03	0.04	0.06	0.23	0.23	0.26	0.28
Morning	0.04	0.06	0.04	0.05	0.25	0.27	0.29	0.33
Pre	0.02	0.04	0.04	0.05	0.25	0.28	0.28	0.30
Post	0.01	0.03	0.04	0.08	0.24	0.27	0.29	0.32

March 19th								
Day	0.03	0.02	0.05	0.05	0.17	0.15	0.17	0.20
Morning	0.05	0.06	0.06	0.09	0.23	0.24	0.24	0.28
Pre	0.04	0.04	0.05	0.09	0.19	0.23	0.25	0.28
Post	0.05	0.03	0.09	0.07	0.24	0.24	0.28	0.25

Table 2.18: Adjusted R^2 for Trade as Dependent Variable

This table reports the average adjusted R^2 for trade CIRFs resulting from 1,000 share trade impulses in each Consolidated data structure, for returns cause trades and trades cause returns assumptions. The first four columns of the table present the adjusted R^2 of trade CIRFs for each Consolidated data structure when returns are assumed to cause trades, but not the opposite. The last four columns in the table present the adjusted R^2 of trade CIRFs for each Consolidated data structure when trades are assumed to cause returns, but not the reverse.

	Adj R^2 (Returns cause Trades)				**Adj R^2 (Trades cause Returns)**			
March 18th	1 Min	2 Min	3 Min	5 Min	1 Min	2 Min	3 Min	5 Min
Day	0.25	0.27	0.26	0.30	0.06	0.09	0.08	0.08
Morning	0.27	0.28	0.30	0.35	0.06	0.07	0.07	0.05
Pre	0.27	0.29	0.29	0.29	0.04	0.06	0.05	0.07
Post	0.28	0.30	0.33	0.34	0.06	0.07	0.09	0.10
March 19th								
Day	0.18	0.17	0.20	0.19	0.05	0.05	0.05	0.05
Morning	0.24	0.26	0.26	0.30	0.09	0.10	0.08	0.11
Pre	0.19	0.23	0.25	0.26	0.04	0.03	0.05	0.05
Post	0.26	0.25	0.28	0.30	0.06	0.06	0.08	0.09

Table 2.18 shows the adjusted R^2s for the trade CIRFs with the returns cause trades and vice versa assumptions. The explanatory power now shifts and the trade impulse under the returns cause trades assumption has significantly higher explanatory power for trades. The conclusion that trades have an impact on prices but no commensurate impact on trades (i.e. do not generate endogenous trading) is based on the trades cause returns assumption. Although the assumption is possibly defensible with respect to the return CIRFs, the side effect of the assumption is to produce a contradictory indicator – returns react to trades as though they are informed but not other trades. Presumably there are not distinct thought processes for returns and trades since they are inextricably linked. Empirically there is no difference in the CIRF calculations, but the outcome is based on the starting assumption which relies on theory. To the extent that the assumption choice rests on the nature of the returns in the data, this assumption is faulty. If returns are viewed as the outcome of passive trades, then the choice is not between trades causing returns or the reverse, but of active or passive trades causing the other. There is no clear-cut reason to favour trades over returns (more properly, passive trades) as the source of

information entering the market. A broadening of the literature to include passive trading activity, as in Brogaard et al. (2019), seems warranted given the identified issues with the return CIRFs compared to observed price changes.

The Forecast Error Variance Decomposition (FEVD) provides an alternative view on the contribution of trades and returns to their respective response functions (Hasbrouck, 1991b). Table 2.19 shows the proportion of the variance of the forecast error for the return and trade CIRFs that is attributable to returns and trades for the *Standard* data structure. For both returns and trades, the majority of the variance is caused by the variable being forecast, but trades play a larger role in the variance of the return CIRF forecast than returns do for the trade CIRF. Whether or not this rules out the possibility of returns causing trades, it does suggest that trades are more important for forecasting returns than vice versa, and the assumption that trades cause returns has more support than its opposite. FEVD results for the *Tradesign* and *Consolidated* data structures mirror those of the *Standard* data structure and have been omitted from Table 2.19.

Table 2.19: FEVD

This table reports the average FEVD for return and trade CIRFs caused by returns and trades for the Standard data structure. The first two columns report the proportion of the variance of the forecast error for the return CIRF that is attributable to returns (By Returns column) and trades (By Trades column). The third and fourth columns report the proportion of the variance of the forecast error for the trade CIRF that is attributable to returns (By Returns column) and trades (By Trades column). For example, the average proportion of the variance in the forecast error for the return CIRFs during the Day on March 18th is 0.93 or 93%.

	Average FEVD for Return CIRFs		**Average FEVD for Trade CIRFs**	
March 18th	By Returns	By Trades	By Returns	By Trades
Day	0.93	0.07	0.01	0.99
Morning	0.92	0.08	0.01	0.99
Pre	0.90	0.10	0.01	0.99
Post	0.92	0.08	0.01	0.99
March 19th				
Day	0.94	0.06	0.01	0.99
Morning	0.94	0.06	0.01	0.99
Pre	0.92	0.08	0.01	0.99
Post	0.92	0.08	0.01	0.99

2.8: Chapter 2 References

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2.9: Chapter 2 Appendix

Appendix 2.1: Negative and Zero Return CIRFs

The number of negative and zero return CIRFs are shown in the tables below. There is one return CIRF per stock per time period for each data structure, but in some cases the VAR model does not produce meaningful results and the total return CIRFs are less than the total number of stocks in the dataset. The stock list contains 82 stocks, with 48 in the cross-listed subgroup and 34 in the non-cross-listed subgroup. Samples where the number of return CIRFs deviate from the total number of stocks are indicated by a * if there is one fewer return CIRF and ** if there are two fewer return CIRFS.

Number of Negative and Zero Return CIRFs - All Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	0	0	1	4	8	6
Morning	0	0	1	6	6	8
Pre	0	0	2	6*	8*	9*
Post	0	0	0	2*	1*	7
March 19						
Day	0	0	4	5	5	8
Morning	0	0	4	9	7	11
Pre	2	0	5	4	8*	11
Post	0	0	3*	10**	10*	14**

Total CIRFs = 82 (* = 81 CIRFs, ** 80 CIRFs)

Number of Negative and Zero Return CIRFs - Cross-listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	0	0	1	2	5	3
Morning	0	0	1	4	3	2
Pre	0	0	1	4*	5*	6**
Post	0	0	0	0*	1*	4
March 19						
Day	0	0	1	1	3	3
Morning	0	0	0	5	2	5
Pre	0	0	1	1	3	3
Post	0	0	2	6**	7	10*

Total CIRFs = 48 (* = 47 CIRFs, ** 46 CIRFs)

Number of Negative and Zero Return CIRFs - Non-Cross-listed Stocks						
March 18	Standard	Tradesign	1 Min	2 Min	3 Min	5 Min
Day	0	0	0	2	3	3
Morning	0	0	0	2	3	6
Pre	0	0	1	2	3	3
Post	0	0	0	2	0	3
March 19						
Day	0	0	3	4	2	5
Morning	0	0	4	4	5	6
Pre	2	0	4	3	5*	8
Post	0	0	1*	4	3*	4*

Total CIRFs = 34 (* = 33 CIRFs)

Appendix 2.2: Maximum Likelihood Estimation and Generalized Method of Moments

Ordinary Least Squares (OLS)

Choose coefficients by minimizing the sum of squared residuals:

$$\min \sum_{i=1}^{N} \left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right)^2 = 0$$

First Order Conditions:

$$\sum_{i=1}^{N} -2\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right) = 0$$

$$\sum_{i=1}^{N} -2x_i\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right) = 0$$

Maximum Likelihood Estimation (MLE)

Assuming the residuals are normally distributed:

$$\iota\left(\sigma^2, {}^{\mu}/_{y}, X\right) = -\frac{n}{2}\log(2\pi) - \frac{n}{2}\log(\sigma)^2 - \frac{1}{2\sigma^2}\sum_{i=1}^{n}\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right)^2$$

Maximizing the log-likelihood function means minimizing the same sum of squared errors as Ordinary Least Squares.

Generalize Method of Moments (GMM)

Find the optimal parameters for: $y_i = \hat{\beta}_0 - \hat{\beta}_1 x_i + \varepsilon$

Population moments:

$$E\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right) = 0$$

$$E\left(x_i\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right)\right) = 0$$

Sample moments:

$$\frac{1}{N}\sum_{i=1}^{N}\left[y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right] = 0$$

$$\frac{1}{N}\sum_{i=1}^{N}\left[x_i\left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right)\right] = 0$$

Multiplying the First Order Conditions for the Ordinary Least Squares by -2 and the Sample Moments by N produces the same First Order Conditions for Ordinary Least Squares and Methods of Moments linear regression models.

Chapter 3: Active Trading Patterns, Passive Order Flow, and Liquidity Impact on Information Measurement of Stock Trading

3.1: Introduction

Microstructure theory provides the link between trading activity and market efficiency on which asset pricing models are built (O'Hara, 2015). If there is a gap in our understanding of the price discovery process, everything that relies on price discovery, including asset-pricing and portfolio management decisions, will be similarly flawed. Assuming that we do not know the information set of traders as they enter orders in the market, we are left to try and infer their information by identifying patterns (the proverbial footprint in the sand) through empirical analysis of market data. The degree to which information impounding models accurately measure the information content of trading activity is important for our understanding of the price discovery process. This Chapter investigates the information measurement properties of the Vector Auto Regression (VAR) model and the effect of active and passive order flow on the VAR model's results. As established in the preceding Chapter, patterns in the market data influence the output of the VAR model, but does this influence persist in the presence of passive order flow, measured by the changes in the price and volume of the best bid and offer (BBO)? Inclusion of BBO data allows for an expansion of the trading patterns that can be analyzed to include the size of the active trade relative to the size of the orders at the BBO. This Chapter argues that the standard VAR model, originated by Hasbrouck (1991), only partially measures information flow into prices by excluding passive order flow that has similar, or greater, influence on prices in a VAR model. Recent models that incorporate passive order flow, such as Brogaard et al. (2019), do not consider the effect of order sequence on the VAR results, missing the importance of "how" prices move in measuring information, not just "how much". The results in this Chapter raise questions about the impact of stock demographics on the VAR results, which are explored with an alternative grouping of subject companies to conclude that VAR measures liquidity (or a lack thereof) instead of information and suffers the VAR equivalent of the liquidity criticisms applied to the Probability of Informed Trading PIN outlined by Duarte and Young (2009). The combination of the order sequence and alternative grouping conclusions suggest VAR is measuring informed

contrarian trading taking advantage of uninformed overreaction, as opposed to information leading to permanent price change. If this conclusion is true, market prices at any point in time convey less information about an asset's value than previously thought and market participants should be cautious about relying on changes in market prices to indicate changes in the value of the underlying asset. Consistent informed contrarian trading implies market prices are far enough from fair value to create profitable trading opportunities.

It is well established in the literature that informed traders act on their information, to earn abnormal profits, and in the process reveal their information by pushing market prices towards their private value (Kyle, 1985), with varying effects on market statistics like the bid-ask spread (Glosten and Milgrom, 1985). Interestingly, if the conclusion that increases in the amount of competition in a market reduces the time it takes for a market to reach the private value of an asset (Holden and Subrahmanyam, 1992), technological innovations in algorithmic trading since the turn of the century should be reflected in the observable patterns in the market data (O'Hara, 2015) and affect our interpretation of those patterns. A number of different models to identify informed trades have been proposed over time. They recognize information as patterns that are not generated randomly, whether by sequence (Hasbrouck, 1991), frequency (Easley et al., 2002), or time (Engle and Russell, 1998). These models, or variations thereof, have become ubiquitous in the trading literature to the point that they have started to attract empirical criticism that challenges their conclusions. Paramount to this critical inquiry is Collin-Dufresne and Fos (2015) who find that measures of informed trading indicate less informed trading on days when the authors could positively identify the presence of informed traders. Earlier work that investigates trading by insiders who were prosecuted by securities authorities produces similar results with respect to increases in liquidity on days when insiders were in the market (Cornell and Sirri, 1992). The impact of liquidity on the VAR model's informed trading measure is analyzed by segmenting the stocks by liquidity, creating two additional groups of stocks. More liquid securities have more direct price changes than less liquid stocks, even in the context of large price changes, resulting in lower VAR measures of informed trading. If the VAR model is accurate, increased liquidity may be masking the presence of informed traders (unless more liquid stocks

have less information impounding, despite being larger, more widely followed, companies), or may be caused by a greater proportion of informed trading. In both cases the ability of the VAR model to accurately measure information flow is uncertain.

All VAR models in this Chapter use tick data from the Toronto Stock Exchange from March 18th and 19th 2009 and include both active trades and passive order flow. The VAR models follow the structure originated by Hasbrouck (1991) and expanded by Brogaard et al. (2019), but with trading volume instead of trade indictors (+1 or -1) and separate return series for bid and ask prices in place of a single return calculated from midpoint prices. Including the size of orders is important to further investigate the impact of order volume on the VAR results. The VAR model is then modified by splitting the *Trades* into different categories. The first division splits *Trades* into *Inflection* (the current *Trade* is in the opposite direction from the preceding *Trade*) and *Non-Inflection* trades, which are contrarian and momentum in nature, respectively. The literature consistently describes profitable contrarian strategies as taking advantage of overreactions by uninformed traders who randomly push prices away from fair value (Campbell et al., 1993; Campbell and Kyle, 1993; Lo and MacKinley, 1990) or who are too slow to close market prices to fair value (L. K. C. Chan et al., 1996; Jegadeesh and Titman, 1995). The *Inflection* trades identified as adhering to a contrarian trading strategy produce similar or higher informed trading measures compared to *Non-Inflection* trades identified as conforming to a momentum strategy. This contradicts the mean reverting nature of the contrarian *Inflection* trade (i.e. not predicated on a permanent price change) and their presumed short-term, liquidity driven basis (Jegadeesh, 1990; Lehmann, 1990), but conforms to the idea that a lack of liquidity, irrespective of the informativeness of the trading, leads to higher VAR measures of information. The importance of the length of a buy or sell sequence before a reversal (i.e. an *Inflection* trade) is explored in the appendix by combining *Inflection* trades and the trade immediately preceding the *Inflection* trade, with *Non-Inflection* trades being all trades which are not *Inflection* and trades immediately preceding *Inflection* trades. The *Inflection* and immediately preceding trades produce lower information measures, indicating that the degree of informed trading in a contrarian strategy depends on the amount of deviation from the mean, as represented by the length of consecutive

trades in the same direction (Caginalp et al., 2000; Lakonishok et al., 1994). This corresponds with the liquidity interpretation of the VAR information measure, as less liquid stocks are more susceptible to uninformed overreaction.

Trades are then split according to their size relative to the bid or ask volume (*Greater Than*, *Equal To*, *Less Than*) when the trade is executed. Non-stealth trading literature predicts that larger trades contain more information that cause, or are revealed by, larger price impact (Biais et al., 2000; Easley and O'Hara, 1987), but the results in this Chapter contradict these conclusions and align with the stealth trading literature that attributes more information to medium sized trades (Alexander and Peterson, 2007; Barclay and Warner, 1993; Chakravarty, 2001; Keim and Madhavan, 1995). Curiously, the medium size trades are simultaneously identified as being informed and stealthy. Although the literature credits institutions who split larger orders into a series of smaller orders[5], authors who investigate known insider trades note that insiders used medium sized orders to try and disguise their trading (Cornell and Sirri, 1992; Jaffe, 1974; Meulbroek, 1992). A final data revision combines the *Inflection*/*Non-Inflection* and trade size categories, with the results showing the expected combination of results from the two preceding trade divisions.

Subperiod analysis splits the data into morning (9:30am – 12:00pm), early afternoon (12:00pm – 2:15pm), and late afternoon (2:15pm – 4:00pm) subperiods. The information measures for the morning period support literature that concludes price discovery and information impounding are higher after a period of no-trading (Amihud and Mendelson, 1987; Amihud and Mendelson, 1991; Amihud et al., 1990). On March 18, 2009 at 2:15pm the Federal Reserve made an announcement inaugurating its Quantitative Easing program, which is why the afternoon is split into early and late afternoon subperiods (referred to as Pre and Post, respectively, in the remainder of this Chapter). If the VAR model measures informed trading, price moves in the late afternoon subperiod on March 18th should not exhibit increases in return CIRFs since the released information is public and not private (i.e. there should be no identifiable trading patterns

[5] These smaller orders are sometimes referred to as "child" orders in the literature and by practitioners.

resulting from the public news release). The VAR results show an uptick in the measured amount of information, which suggests that VAR is not distinguishing between informed and uninformed trading but is linking any trading activity with any price movement. If the value of public information has been underestimated in the literature (K. C. Chan et al., 1996) or the market is slow to price the public information (Hong and Stein, 1999; Riordan et al., 2013) the VAR model will pick up the apparent informed trading. The VAR results may also be picking up differences in how different trading strategies, contrarian and momentum, are informed differently about individual stock returns vs. market returns (Lei and Wu, 2005).

The TAQ data covers 82 stocks, which are initially divided into cross-listed (stocks that are listed on an exchange outside of Canada, primarily NYSE or NASDAQ) and non-cross-listed (stocks that are only listed on the Toronto Stock Exchange). The two subgroups show differences in some of the calculated CIRFs that are significant enough to reverse the interpretation of the trading as being informed or uninformed. For example, passive order flow CIRFs for the two subgroups are in opposite directions, indication the market interprets passive orders as informed for the cross-listed subgroup but uninformed for the non-cross-listed subgroup. This may be a reflection of information transfer between the cross-listed markets, where one market or the other impounds information first (Hasbrouck, 1995). As this article does not look at TAQ data for the corresponding non-Canadian market, it is not clear if this effect is present or the direction of the information transfer. Further complicating the subgroup issue, rearranging the subgroups by liquidity changes the VAR results enough that it calls into question the previous results and implies that the VAR model is actually a measure of liquidity as opposed to information. The remainder of the paper is divided into a Data (section 3.2), Methodology (section 3.3), and Results (section 3.4) section. The Results section presents the results of each model, distinguished by the organization of the trade data, before recasting the VAR model results with liquidity based subgroups.

3.2: Data

The data is from the Toronto Stock Exchange (TSX) and is comprised of tick data for the regular trading sessions on March 18 and March 19, 2009. Each day is divided into four different subperiods: Day covers the entire trading day from 9:30am to 4:00pm, Morning from 9:30am to 12:00pm, Pre from 12:00pm to 2:15pm, and Post from 2:15pm to 4:00pm. The rationale for the Pre and Post time split comes from a Federal Open Market Committee (FOMC) announcement that occurs at 2:15pm on March 18th which announces the beginning of the Federal Reserve's Quantitative Easing program. The announcement caused a significant increase in prices for certain stocks in the data, particularly gold mining companies. The data set includes 82 stocks in the S&P/TSX Composite index as it existed in March 2009. 48 of the stocks are also listed on a US exchange and therefore constitute the Cross-Listed subgroup, the other 34 stocks form the Non-Cross-Listed subgroup. The tick data contains all trades and quotes at the best bid and offer. Odd lots (trades below 100 shares) are removed, leaving only trades in the regular or board lot market (odd lots are posted in a separate book and trade exclusively with the designated market marker for each stock).

The focus of this paper is on all trading decisions made by market participants, as represented by all orders entered on the marketplace. The passive order flow is included in the data, not just the active trades. To represent the passive order flow, four variables are created: *Change to Existing Bid*, *New Bid*, *Change to Existing Ask*, and *New Ask*. The passive variables are used in all the VAR models in this Chapter. *Change to Existing Bid* and *Ask* measure the change in the size (number of shares) of the best bid and ask, respectively. If the bid or ask size increases, a positive change is recorded. If the bid or ask size decreases, a negative change is recorded. These changes in the bid and ask sizes exclude changes caused by trades, to include decision making only with respect to the passive exposure of a bid or ask at the top of the book. Each change in an existing bid or ask is caused by the entry or cancellation of a single order. *New Bid* measures the change in the size of a bid (number of shares) that causes a change in the bid price. A positive entry indicates the *New Bid* price was higher than the previous best bid – the *New Bid* is the addition of liquidity

in the market, signed to the direction of the price change. A negative *New Bid* indicates the *New Bid* price is lower than the previous best bid and results from the cancellation of the previous best bid – the size is the size of the last bid at the previous best bid price, which is cancelled, signed to the direction of the change in the bid price. Similar to the *Change to Existing Bid*, *New Bid* changes are not the result of active trades. *New Ask* reciprocates *New Bid* for changes in size of an ask that result in a *New Ask* price. The sign of the change is again matched to the change in the ask price – a negative *New Ask* is the size of a *New Ask* (number of shares) that is entered at a lower ask price than the previous ask price; a positive *New Ask* is the size of an ask that is cancelled and results in a new, higher ask price. *New Ask* changes are again not the result of trading activity, but the independent decision to add or remove that passive order exposure from the market. The distinction between the changes in the existing bid and ask sizes and *New Bid* and *Ask* sizes is the concomitant change in price with a *New Bid* and *Ask*, although they both describe passive order flow at the top of the book.

The tick data presents each individual execution from a trade, as a single trade may interact with multiple posted bids and asks. These individual executions are consolidated into a single trade, regardless of how many passive orders were filled, representing the active trades in the market. Buys (sells), defined as a trade that executes at the best ask (bid) price or higher (lower), are positively (negatively) signed, with midpoint crosses (i.e. trades that do not occur at the best bid or ask price) removed as they cannot be reliably determined to be either a buy or sell. This is the base data for all the trade variables and is used as the *Trade* variable in VAR Model 1.

Trades are then divided into two different sets of categories: *Inflection*/*Non-Inflection* and *Greater Than*/*Equal To*/*Less Than*. *Inflection* trades are trades that are in the opposite direction of the immediately preceding trade (i.e. if the previous trade was a buy, a sell trade would be coded as an *Inflection* trade). *Trades* that are in the same direction as the immediately preceding trade are coded as *Non-Inflection* trades. *Inflection* trades represent trades that are counter to the trading sequence (contrarian trades) while *Non-Inflection* trades represent the persistence of an existing sequence (momentum trades). VAR Model 2 replaces the *Trade* variable with

Inflection and *Non-Inflection* trades. *Greater Than*/*Equal To*/*Less Than* separate trades by the difference between the size of the trade and size of the bid or ask when the trade was executed. The size of the bid or ask is the total volume at the best bid or ask price for all posted orders. If the trade volume (or total number of shares executed by the trade) exceeds the posted bid or ask volume, the trade is coded as *Greater Than*. Similarly, trades that are the same size or smaller than the posted bid or ask are coded as *Equal To* and *Less Than*, respectively. The *Trade* variable is replaced by the *Greater Than*/*Equal To*/*Less Than* variables in VAR Model 3. The final categorization separates *Inflection*/*Non-Inflection* trades in each of the *Greater Than*/*Equal To*/*Less Than* trade categories. This highest level of granularity poses some problems for smaller data sets which do not contain sufficient data points for all of the six trade categories to produce statistically meaningful results.

3.3: Methodology

The Vector Auto Regression (VAR) model used by Hasbrouck (1991) premises the measurement of information by evaluating the sequence of trades and returns. In short, if returns can be explained by preceding trades, the preceding trades contain information about prices. Since the price changes must be permanent, the returns explained by trading activity are estimated using a Cumulative Impulse Response Function (CIRF) that calculates the predicted return from a trade impulse over some number of ticks or periods. Hasbrouck's model captures active trading activity in a trade variable, with all other variables indirectly represented by a return variable. Subsequent research has expanded the number of independent variables in the model, particularly passive order flow. Fleming et al. (2018) adds variables measuring the volume of passive limit orders entered and canceled for US Treasury bonds, while Brogaard et al. (2019) includes High Frequency Trader and non-High Frequency Trader order additions and cancellations to the market book, at both the National Best Bid and Offer (NBBO) and more than 1 tick from the NBBO. Both articles conclude that the passive order flow, by virtue of its contribution to return CIRFs, contains information about prices. Boulatov and George (2013) find that informed liquidity providers benefit from information advantages about liquidity, while

Mizrach (2008) uses a VAR model to show that the entire limit order book influences the next trade. In this Chapter, four VAR models are estimated, each closely following the equations from Brogaard et al. (2019):

$$X_t^1 = \sum_{i=1}^{k} \beta_i^{1,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{1,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{1,m} X_{t-i}^m + u_t^1$$
$$X_t^2 = \sum_{i=1}^{k} \beta_i^{2,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{2,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{2,m} X_{t-i}^m + u_t^2$$
$$\vdots =$$
$$X_t^m = \sum_{i=1}^{k} \beta_i^{m,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{m,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{m,m} X_{t-i}^m + u_t^m \qquad \textit{(eq 3.1)}$$

where the *m* index indicates the variable, *i* is the lag, and *k* is the total number of lags (estimated separately for each stock using AIC). Each of the four VAR models uses a different set of variables for active trades, but the same variables for passive trades (Table 3.1). The variable *t* measures each tick, therefore the model exists in "tick time" where each event constitutes an observation. Bid and ask price changes are tracked separately, producing distinct bid and ask returns. In some ticks, the bid and ask prices change simultaneously because an order changes both the bid and ask prices (i.e. a buy/sell order fills the ask/bid volume with unfilled volume that establishes a *New Bid*/*Ask* price) and could be considered to occur contemporaneously in the time series (Appendix 3.1 shows the proportion and bid and ask price observations when the bid and ask prices change in the same tick). In other cases, only the bid or ask price changes in response to a sell or buy trader, or passive order flow. To avoid a proliferation of variables that encompass a large number of contemporaneous or lagged interactions[6], all observations are assumed to occurred as distinct ticks. This preserves the sequence of events, but places more ticks between some observations, such as consecutive trades that cause a quote revision, than a model that assumes trades cause returns contemporaneously.

[6] There are other distinctions in the data, such as intentional crosses or trades filling dark orders, which cannot contemporaneously alter the NBBO.

Table 3.1: VAR Model Variables

	VAR Model 1	VAR Model 2	VAR Model 3	VAR Model 4
X^1	Trade	Inflection Trade	Greater Than Trade	Greater Than Inflection Trade
X^2	Change to Existing Bid	Non-Inflection Trade	Equal To Trade	Equal To Inflection Trade
X^3	New Bid	Change to Existing Bid	Less Than Trade	Less Than Inflection Trade
X^4	Bid Price Change	New Bid	Change to Existing Bid	Greater Than Non-Inflection Trade
X^5	Change to Existing Ask	Bid Price Change	New Bid	Equal To Non-Inflection Trade
X^6	New Ask	Change to Existing Ask	Bid Price Change	Less Than Non-Inflection Trade
X^7	Ask Price Change	New Ask	Change to Existing Ask	Change to Existing Bid
X^8		Ask Price Change	New Ask	New Bid
X^9			Ask Price Change	Bid Price Change
X^{10}				Change to Existing Ask
X^{11}				New Ask
X^{12}				Ask Price Change

Unlike the model used in Brogaard et al. (2019), which uses +1 or -1 for trade observations (both active and passive) and midpoint price changes to measure returns, this Chapter uses volumes (measured in number of shares) and separately calculates returns for changes in bid prices and ask prices. The rationale for using volumes stems from the results found in Chapter 2, which identify trading patterns related to volumes that affect the VAR results; excluding trade volumes explicitly ignores the potential impact of trade size on information impounding. If trade volumes conform to the conclusions from the stealth trading literature, medium sized trades should exert more influence than larger trades (Alexander and Peterson, 2007; Chakravarty, 2001) instead of the reverse (Easley and O'Hara, 1987), but more importantly, if the VAR model results are affected by the size of the trade then volumes cannot be ignored in information measurement models. The impact of trade size relative to passive orders is explicitly explored in VAR models 3 and 4. Bid and ask returns are calculated separately to examine changes in the bid-ask spread resulting from active and passive order flow, although not using price midpoints to measure returns adds a degree of noise to the return data.

The results section reports the return and order flow CIRFs for all of the variables in each VAR model. The focus of price impounding research is on the price impact, or return CIRFs, but the responses of the other variable point to the mechanics that generate the return CIRFs and provide important insights that aid in interpreting the return CIRFs. Granger-causality and a battery of tests of randomness are calculated for each model and presented in the appendices. The VAR models may present a problem, which seems difficult to resolve (assuming the problem exists). The VAR models include bid and ask returns as a variable, which in past models, such as Hasbrouck (1991), accounted for excluded variables (passive order flow). The VAR models used in this paper, and in Brogaard et al. (2019), include all variables at the best bid and offer and therefore all of the variables that are used in the return calculation (i.e. all of the changes in the passive orders that would result in a change in bid or ask price). In other words, the observed bid and ask prices cannot change without an entry for one of the variables included in the VAR models. There is no mechanism in the observed data for a bid or ask return to directly cause a bid or ask return, any effect would be indirect and captured by subsequent order flow. The predicted bid and ask returns, however, include lagged bid and ask returns as explanatory variables, as well as an error term. Past bid and ask returns have a direct impact on predicted bid and ask returns, in addition to an indirect effect operating through the predicted order flow; the mechanism that produces the predicted values is different than the mechanism in the observed data. The VAR model may be over specified with respect to the bid and ask return equations and double count the impact of past bid and ask returns or correlate with the error term. Since the equations are estimated simultaneously, over specification of the return variables would imply overspecification of the whole model. Removing the return variables is not possible as they are the variables of interest and past values would undoubtably influence current order flow, but the return and order flow CIRFs may overstate the explanatory power of the VAR model.

3.4: Results

3.4.1: VAR Model 1

Table 3.2 contains the return CIRFs for impulses from each of the active and passive trade variables in VAR model 1. The first column, Midpoint % Change, is the average midpoint return of each subgroup of stocks for each subperiod. The second column contains the return CIRFs for the VAR model which uses midpoint returns and a single trade series, producing a single (midpoint) return CIRF from the trade impulse, such as the 0.089% return CIRF for the entire Day of March 18 (the "Standard" VAR model). The VAR models in this Chapter use separate bid and ask returns, which are represented by two return CIRFs for each order flow impulse in each subperiod. The results from VAR model 1 are presented starting in the third column, with each column header indicating the order flow impulse that produced the return CIRFs in each column. The first row for each subperiod is the bid return CIRF (e.g. in column 3, 0.065% for a 1,000 share *Trade* for the Day of March 18) and the second row is the ask return CIRF (e.g. in column 3, 0.076% for a 1,000 share *Trade* for the Day of March 18). This differs from prior literature that uses the midpoint return and allows for analysis of the bid-ask spread impact of active and passive order flow. To continue the example, a 1,000 share *New Bid* reduces the bid-ask spread as the bid return CIRF exceeds the ask return CIRF. This distinguishes passive trading from active trading, which tends to produce a widening of the bid-ask spread. Passive orders, unlike active orders, have a distinctly higher impact on their own return response (i.e. bid side impulses induce a greater response for the bid return, with the opposite happening for ask impulses). This tightens or widens the spread in direct relation to the passive order, generally tightening the spread when liquidity increases and widening when liquidity decreases, suggesting an adverse selection problem with respect to passive orders. In contrast, active trades have no apparent impact on the spread, contrary to the traditional assumption of information content in active trades and their impact on the bid-ask spread.

Both the bid and ask return CIRFs from the active trade impulses in VAR Model 1 are generally lower than the midpoint return CIRFs generated in the Standard trade and return VAR model from Hasbrouck (1991), calculated in Chapter 2. This result corresponds with Mizrach (2008) that the absence of passive order flow in the VAR model overestimates the impact of active trades. Passive order impulses also produce a response, which is larger for some variables than active trades. For example, the return CIRF for a 1,000 share *New Bid* on the morning of March 18 for Cross-Listed stocks is 0.112%, but the 1,000 share *Trade* (which would execute against the posted offers) induces a return response of only 0.073%. The passive order is more influential than the active order.

Table 3.2: Average Return CIRFs for Active and Passive *Trade* Impulses

This table reports the average return CIRFs for the VAR model from Chapter 2 in the *Standard* column, and the average return CIRFs for VAR Model 1 in columns 3 through 7, with each column presenting the average return CIRFs for the order impulse in the column header (for example, the order impulse in column 3 is a *Trade*, and in column 4 a *Change to Existing Bid*). Average CIRFs are reported for each subperiod, with cross-listed and non-cross-listed subgroup CIRFs presented in separate panels. The VAR Model 1 average return CIRFs have two entries for each subperiod, the first result is the average bid return CIRF and the second result is the average ask return CIRF. For example, the bid return CIRF for a *Trade* Impulse in VAR Model 1 on March 18th during the day is 0.065% for cross-listed stocks. The corresponding ask return CIRF is 0.076%. The return CIRF is the price change forecast to occur over a 100-tick period following the indicated order impulse. The Midpoint price changes over each subperiod are included in the first column for reference. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each average return CIRF.

Average Return CIRFs for given impulse - Cross-listed

		Standard	VAR Model 1				
March 18	Midpoint % Change	Trade Impulse	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	2.133%	0.089%	0.065% 0.0	0.021% 0.0	0.094% 0.0	-0.013% 0.0	0.022% 0.0
			0.076% 0.0	0.012% 0.0	0.020% 0.0	-0.020% 0.0	0.097% 0.0
Morning	-0.782%	0.086%	0.073% 0.0	0.018% 0.0	0.112% 0.0	-0.009% 0.0	0.019% 0.0
			0.072% 0.0	0.009% 0.0	0.017% 0.0	-0.018% 0.0	0.103% 0.0
Pre	0.686%	0.068%	0.054% 0.0	0.017% 0.0	0.115% 0.0	-0.010% 0.0	0.018% 0.0
			0.076% 0.0	0.009% 0.0	0.020% 0.0	-0.015% 0.0	0.111% 0.0
Post	2.244%	0.086%	0.069% 0.0	0.022% 0.0	0.098% 0.0	-0.018% 0.0	0.026% 0.0
			0.078% 0.0	0.013% 0.0	0.021% 0.0	-0.026% 0.0	0.117% 0.0

March 19							
Day	-0.741%	0.066%	0.048%	0.015%	0.086%	-0.011%	0.018%
			0.0	0.0	0.0	0.0	0.0
			0.049%	0.008%	0.013%	-0.016%	0.089%
			0.0	0.0	0.0	0.0	0.0
Morning	-0.417%	0.084%	0.063%	0.022%	0.102%	-0.011%	0.020%
			0.0	0.0	0.0	0.0	0.0
			0.068%	0.010%	0.015%	-0.021%	0.100%
			0.0	0.0	0.0	0.0	0.0
Pre	0.344%	0.047%	0.043%	0.011%	0.095%	-0.011%	0.014%
			0.0	0.0	0.0	0.0	0.0
			0.042%	0.006%	0.014%	-0.015%	0.091%
			0.0	0.0	0.0	0.0	0.0
Post	-0.667%	0.039%	0.033%	0.010%	0.089%	-0.008%	0.012%
			0.0	0.0	0.0	0.0	0.0
			0.036%	0.006%	0.014%	-0.010%	0.089%
			0.0	0.0	0.0	0.0	0.0

Return CIRFs for given impulse - Non-Cross-listed

		Standard	VAR Model 1				
March 18	Midpoint % Change	Trade Impulse	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	1.319%	0.089%	0.088%	0.042%	0.147%	-0.015%	0.030%
			0.0	0.0	0.0	0.0	0.0
			0.075%	0.022%	0.025%	-0.031%	0.146%
			0.0	0.0	0.0	0.0	0.0
Morning	-0.849%	0.104%	0.099%	0.049%	0.166%	-0.015%	0.030%
			0.0	0.0	0.0	0.0	0.0
			0.083%	0.023%	0.022%	-0.037%	0.168%
			0.0	0.0	0.0	0.0	0.0
Pre	0.779%	0.065%	0.057%	0.026%	0.146%	-0.005%	0.015%
			0.0	0.0	0.0	0.27	0.0
			0.056%	0.013%	0.015%	-0.014%	0.139%
			0.0	0.0	0.0	0.0	0.0
Post	1.411%	0.095%	0.087%	0.031%	0.176%	-0.010%	0.022%
			0.0	0.0	0.0	0.0	0.0
			0.075%	0.016%	0.018%	-0.024%	0.159%
			0.0	0.0	0.0	0.0	0.0
March 19							
Day	-1.713%	0.082%	0.077%	0.031%	0.122%	-0.023%	0.027%
			0.0	0.0	0.0	0.0	0.0
			0.068%	0.009%	0.016%	-0.042%	0.138%
			0.0	0.0	0.0	0.0	0.0
Morning	-1.075%	0.104%	0.095%	0.036%	0.129%	-0.025%	0.030%
			0.0	0.0	0.0	0.0	0.0
			0.083%	0.005%	0.014%	-0.045%	0.150%
			0.0	0.19	0.0	0.0	0.0
Pre	-0.297%	0.070%	0.074%	0.024%	0.172%	-0.014%	0.023%
			0.0	0.0	0.0	0.0	0.0
			0.064%	0.007%	0.018%	-0.039%	0.170%
			0.0	0.08	0.0	0.0	0.0
Post	-0.354%	0.050%	0.050%	0.022%	0.140%	-0.012%	0.027%
			0.0	0.0	0.0	0.0	0.0
			0.051%	0.007%	0.016%	-0.027%	0.136%
			0.0	0.04	0.0	0.0	0.0

We can further investigate the mechanism by which active and passive trades impact prices by looking at the sources of the return CIRFs, broken down by variable (Tables 3.3, 3.4, and 3.5). Table 3.3 presents the breakdown for a 1,000 share active trade impulse. This highlights that there may not be a single method of information processing for all stocks, but different processes for different stocks. For example, for cross-listed stocks, adding in the passive trading information reduces the return CIRF for a trade impulse (the "Trade Impulse" column under VAR Model 1 in the top panel of Table 3.2) compared to the model that excludes passive trades in favour of a single order flow series (the "Trade Impulse" column under Standard in the top panel of Table 3.2). The drop in the return CIRFs for non-cross-listed stocks are smaller, and in one case larger, in the presence of passive order flow. The first column in Tables 3.3, 3.4, and 3.5 report the bid return CIRFs for the impulse used in each table. The remaining columns show the contribution of each variable to the bid return CIRF. For example, in Table 3.3 the *Trade* variable contributes 0.0745% to the bid return CIRF for the entire day on March 18, as shown in the first row of the by *Trade* column. The sum of the "by" columns is the bid return CIRF shown in the CIRF column.

For both the cross-listed and non-cross-listed subgroups, the primary return CIRF driver is the active trade with previous bid returns acting as a dampener for the return response, reversing about a third of the active trade's price impact (e.g. for the Day of March 18 in the cross-listed subgroup, the bid return contribution of -0.0293% is material compared to the 0.0745% contribution of the active trade). The mean reverting nature of returns from the Standard VAR model is maintained for returns on the opposite side of the active trade (i.e. bids for buy trades and ask for sell trades). Ask return CIRFs, however, move in the same direction as the trade, indicating a different reaction by the side of the market that is transacting with the trade (i.e. the 0.012% bid return CIRF contribution in the first row of the by Ask Price Change column). For a buy trade, the buying side of the market reacts as though the buy trade does not contain information, or the bid return response is an overreaction, while the ask side of the market reacts as though the trade contains information. This may highlight a behavioral difference that depends on whether you are on the side of the market at risk of transacting (adverse selection)

or not (liquidity seeking). This pattern is roughly similar between the two subgroups, with the non-cross-listed subgroup experiencing a relatively stronger impact from a trade impulse, combined with a mix of passive order effects, some of which are mean reverting (i.e. the March 19 by *Change to Existing Bid* column in Table 3.3 for non-cross-listed stocks).

The difference in the size of the by Bid Price Change contribution to the bid return CIRF compared to the other indirect (i.e. not *Trade*) components is curious. The model accounts for all order flow, including order flow that results in a change in the bid price. Yet, by Bid Price Change remains the most influential component of the bid return CIRF besides the *Trade* impulse variable. I am not sure if this signals that there is a problem with the VAR model specification. Perhaps the VAR model should not include autoregressive terms for returns, as it may be double counting effects captured by the other variables (i.e. past passive and active trades that generated the changes in the bid and ask prices).

Table 3.3: Bid Return CIRF breakdown for 1,000 share *Trade* Impulse

The table below reports the components of the average bid return CIRFs for VAR Model 1 from a *Trade* impulse (the bid return CIRFs from column 3 in Table 3.2) over a 100-tick period following the impulse. The average bid return CIRF is in column 1, with the contribution of each variable presented in columns 2 through 8; column 1 is the sum of columns 2 through 8. The contribution of *Trade* in column 2 is created by both the exogenous *Trade* impulse and its endogenous response. The remaining variables contribute solely through their response to the *Trade* impulse. Subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Bid Price CIRF for 1,000 Trade impulse by component - Cross-listed Stocks

VAR Model 1

March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0655%	0.0745%	0.0011%	0.0065%	-0.0293%	0.0005%	0.0003%	0.0120%
	0.0	0.0	0.0	0.0	0.0	0.14	0.01	0.0
Morning	0.0727%	0.0856%	0.0007%	0.0077%	-0.0307%	0.0006%	0.0002%	0.0086%
	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.0
Pre	0.0536%	0.0527%	-0.0004%	0.0044%	-0.0150%	-0.0007%	0.0009%	0.0118%
	0.0	0.0	0.66	0.07	0.0	0.61	0.34	0.0
Post	0.0691%	0.0779%	0.0016%	0.0058%	-0.0289%	0.0007%	0.0002%	0.0119%
	0.0	0.0	0.0	0.14	0.0	0.16	0.01	0.0

March 19								
Day	0.0479%	0.0501%	0.0007%	0.0053%	-0.0168%	0.0007%	-0.0001%	0.0080%
	0.0	0.0	0.0	0.0	0.0	0.0	0.47	0.0
Morning	0.0628%	0.0678%	0.0008%	0.0064%	-0.0226%	0.0007%	-0.0003%	0.0101%
	0.0	0.0	0.0	0.0	0.0	0.0	0.28	0.0
Pre	0.0429%	0.0438%	0.0002%	0.0057%	-0.0142%	0.0012%	-0.0001%	0.0064%
	0.0	0.0	0.62	0.0	0.0	0.0	0.43	0.0
Post	0.0333%	0.0321%	0.0006%	0.0036%	-0.0082%	0.0005%	-0.0002%	0.0050%
	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.0

Bid Price CIRF for 1,000 Trade impulse by component - Non-Cross-listed Stocks

VAR Model 1

March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0879%	0.0962%	0.0006%	0.0116%	-0.0328%	0.0002%	0.0008%	0.0112%
	0.0	0.0	0.0	0.0	0.0	0.46	0.01	0.0
Morning	0.0989%	0.1091%	0.0005%	0.0083%	-0.0339%	0.0008%	0.0023%	0.0119%
	0.0	0.0	0.16	0.0	0.0	0.08	0.01	0.0
Pre	0.0567%	0.0545%	0.0000%	0.0093%	-0.0114%	-0.0005%	-0.0001%	0.0049%
	0.0	0.0	0.96	0.0	0.0	0.06	0.50	0.0
Post	0.0866%	0.0957%	0.0004%	0.0135%	-0.0293%	0.0000%	0.0005%	0.0058%
	0.0	0.0	0.35	0.0	0.0	1.0	0.12	0.0
March 19								
Day	0.0768%	0.0920%	-0.0005%	0.0032%	-0.0304%	0.0013%	0.0011%	0.0101%
	0.0	0.0	0.43	0.07	0.0	0.07	0.03	0.0
Morning	0.0946%	0.1128%	-0.0007%	0.0039%	-0.0351%	0.0016%	0.0011%	0.0111%
	0.0	0.0	0.40	0.01	0.0	0.0	0.07	0.0
Pre	0.0744%	0.0829%	-0.0003%	0.0024%	-0.0159%	0.0003%	0.0000%	0.0050%
	0.0	0.0	0.53	0.21	0.0	0.41	0.96	0.0
Post	0.0500%	0.0580%	-0.0002%	0.0027%	-0.0150%	0.0002%	0.0010%	0.0033%
	0.0	0.0	0.60	0.38	0.0	0.59	0.14	0.0

Table 3.4, which uses a passive order for the impulse, paints a different picture. When we look at the bid return CIRFs caused by a 1,000 share change in the size of an existing bid, it is apparent that there is a different mechanism at work. The primary driver of the bid return CIRFs is *New Bids*, not *Change to Existing Bid*, which is unexpected as the largest effect is now indirect (i.e. the largest contribution to the bid return CIRFs are found in the by *New Bid* column) instead of being caused by the direct shock (the by *Change to Existing Bid* column). At the same time that changes in existing bids create price pressure from *New Bids*, the response of the *New Ask* passive variable in the by *New Ask* column indicates that the reaction of sellers is to offer lower prices (i.e. enter new, lower price offers, in response to increases in the size of the existing bid). New bids treat the change in size of an existing bid as an information event, trading in the same direction as the *Change to Existing Bid*. Although this could be a competitive liquidity seeking reaction, with *New Bids* attempting to move ahead of a now longer queue at the best bid price, it will register in the

VAR model as information flow because it causes a change in the bid price. Conversely, the ask side of the market treats the *Change to Exiting Bids* as a liquidity event, with neutral to negative reaction (i.e. pushing bid prices downwards). The liquidity seeking response is more pronounced in the non-cross-listed subgroup, which is composed of less liquid stocks, supporting the idea that opposing sides of the market treat passive order flow as uninformed.

Table 3.4: Bid Return CIRF breakdown for 1,000 share *Change to Existing Bid*

The following table presents the components of the average bid return CIRFs for VAR Model 1 from *a Change to Existing Bid* impulse (the bid return CIRFs from column 4 in Table 3.2) over a 100-tick period following the impulse. The bid return CIRF is in column 1, with the contribution of each variable presented in columns 2 through 8; column 1 is the sum of columns 2 through 8. The contribution of *Change to Existing Bid* in column 3 is created by both the exogenous *Change to Existing Bid* impulse and its endogenous response. The remaining variables contribute solely through their response to the *Change to Existing Bid* impulse. Subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Cross-listed Stocks
VAR Model 1

	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
March 18								
Day	0.0211%	0.0014%	0.0140%	0.0117%	-0.0084%	0.0000%	0.0001%	0.0023%
	0.0	0.01	0.0	0.0	0.0	0.92	0.14	0.0
Morning	0.0183%	0.0015%	0.0074%	0.0155%	-0.0079%	0.0002%	0.0001%	0.0015%
	0.0	0.06	0.0	0.01	0.0	0.04	0.32	0.0
Pre	0.0166%	0.0007%	0.0065%	0.0121%	-0.0042%	-0.0001%	0.0001%	0.0014%
	0.0	0.43	0.0	0.01	0.0	0.80	0.72	0.0
Post	0.0224%	0.0021%	0.0135%	0.0119%	-0.0086%	0.0005%	0.0002%	0.0028%
	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0
March 19								
Day	0.0145%	0.0004%	0.0067%	0.0106%	-0.0050%	0.0003%	0.0000%	0.0016%
	0.0	0.40	0.0	0.0	0.0	0.09	0.67	0.0
Morning	0.0217%	0.0014%	0.0059%	0.0193%	-0.0072%	0.0007%	-0.0005%	0.0021%
	0.0	0.03	0.01	0.01	0.0	0.08	0.42	0.0
Pre	0.0107%	-0.0003%	0.0057%	0.0071%	-0.0025%	0.0001%	-0.0003%	0.0010%
	0.0	0.66	0.0	0.0	0.01	0.62	0.06	0.0
Post	0.0099%	0.0006%	0.0047%	0.0059%	-0.0025%	0.0002%	-0.0001%	0.0011%
	0.0	0.0	0.0	0.0	0.0	0.31	0.03	0.0

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Non-Cross-listed Stocks								
	VAR Model 1							
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0419%	0.0054%	0.0059%	0.0474%	-0.0155%	-0.0031%	-0.0015%	0.0034%
	0.0	0.04	0.11	0.0	0.0	0.0	0.07	0.0
Morning	0.0490%	-0.0003%	0.0128%	0.0550%	-0.0166%	-0.0026%	-0.0030%	0.0038%
	0.0	0.91	0.01	0.0	0.0	0.0	0.05	0.0
Pre	0.0256%	0.0036%	0.0040%	0.0260%	-0.0063%	-0.0017%	-0.0012%	0.0011%
	0.0	0.01	0.23	0.0	0.0	0.02	0.18	0.01
Post	0.0312%	0.0060%	-0.0044%	0.0428%	-0.0115%	-0.0025%	-0.0007%	0.0014%
	0.0	0.12	0.55	0.0	0.0	0.01	0.19	0.0
March 19								
Day	0.0313%	-0.0048%	0.0194%	0.0379%	-0.0131%	-0.0053%	-0.0042%	0.0015%
	0.0	0.35	0.01	0.0	0.0	0.0	0.02	0.0
Morning	0.0358%	-0.0052%	0.0214%	0.0421%	-0.0156%	-0.0031%	-0.0052%	0.0015%
	0.0	0.26	0.04	0.0	0.0	0.0	0.02	0.01
Pre	0.0238%	-0.0010%	0.0099%	0.0242%	-0.0059%	-0.0020%	-0.0019%	0.0005%
	0.0	0.75	0.03	0.0	0.0	0.0	0.01	0.08
Post	0.0216%	-0.0039%	0.0103%	0.0277%	-0.0060%	-0.0045%	-0.0026%	0.0006%
	0.0	0.26	0.0	0.0	0.0	0.0	0.01	0.27

Table 3.5 provides yet another perspective on the information impounding process. New bids have the largest bid return CIRF, with different contributions from the other components than the preceding *Trade* and *Change to Existing Bid* impulses. Although changes in the size of an existing bid produces a stronger effect from *New Bids*, the opposite is not true (i.e. most of the *New Bids* impact on the bid return CIRF is direct). Active trades react negatively to *New Bids* in some subperiods, indicating that active trading is behaving in a mean reverting/liquidity seeking pattern. The ask side of the market reacts similarly. The bid return CIRF indicates that there is information content in the *New Bid* (and more than an equivalently sized active trade), but the active trading response indicates the opposite, unless active trades are uninformed (at least in response to the *New Bid* impulse). Again, there is a difference in how existing asks respond for the cross-listed and non-cross-listed subgroups and bid returns act as a dampening force on the bid return CIRF.

Table 3.5: Bid Return CIRF breakdown for 1,000 share *New Bid*

This table presents the components of the average bid return CIRFs for VAR Model 1 from a *New Bid* impulse (the bid return CIRFs from column 5 in Table 3.2) over a 100-tick period following the impulse. The bid return CIRF is in column 1, with the contribution of each variable presented in columns 2 through 8; column 1 is the sum of columns 2 through 8. The contribution of *New Bid* in column 4 is created by both the exogenous *New Bid* impulse and its endogenous response. The remaining variables contribute solely through their response to the *New Bid* impulse. Subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the

null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Bid Price CIRF for 1,000 New Bid impulse by component - Cross-listed Stocks

VAR Model 1

March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0936%	0.0010%	0.0034%	0.1266%	-0.0420%	0.0002%	0.0002%	0.0041%
	0.0	0.46	0.0	0.0	0.0	0.22	0.07	0.0
Morning	0.1121%	-0.0011%	0.0017%	0.1540%	-0.0457%	0.0002%	0.0001%	0.0031%
	0.0	0.45	0.0	0.0	0.0	0.08	0.71	0.0
Pre	0.1145%	-0.0009%	0.0028%	0.1410%	-0.0312%	0.0002%	0.0002%	0.0026%
	0.0	0.51	0.0	0.0	0.0	0.63	0.43	0.0
Post	0.0983%	0.0004%	0.0026%	0.1314%	-0.0410%	0.0005%	0.0002%	0.0042%
	0.0	0.53	0.0	0.0	0.0	0.03	0.20	0.0
March 19								
Day	0.0861%	-0.0009%	0.0016%	0.1115%	-0.0294%	0.0004%	0.0000%	0.0029%
	0.0	0.08	0.0	0.0	0.0	0.0	0.84	0.0
Morning	0.1019%	0.0001%	0.0009%	0.1333%	-0.0364%	0.0006%	-0.0001%	0.0034%
	0.0	0.81	0.21	0.0	0.0	0.01	0.71	0.0
Pre	0.0954%	-0.0021%	0.0024%	0.1222%	-0.0298%	0.0005%	-0.0005%	0.0027%
	0.0	0.17	0.0	0.0	0.0	0.03	0.02	0.0
Post	0.0894%	-0.0009%	0.0017%	0.1054%	-0.0192%	0.0005%	-0.0004%	0.0024%
	0.0	0.17	0.0	0.0	0.0	0.01	0.0	0.0

Bid Price CIRF for 1,000 New Bid impulse by component - Non-Cross-listed Stocks

VAR Model 1

March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.1472%	-0.0015%	0.0012%	0.1995%	-0.0538%	-0.0021%	-0.0012%	0.0053%
	0.0	0.44	0.10	0.0	0.0	0.0	0.04	0.0
Morning	0.1663%	-0.0023%	0.0034%	0.2141%	-0.0492%	-0.0018%	-0.0032%	0.0055%
	0.0	0.28	0.07	0.0	0.0	0.01	0.04	0.0
Pre	0.1464%	-0.0008%	0.0012%	0.1772%	-0.0290%	-0.0016%	0.0010%	-0.0016%
	0.0	0.75	0.13	0.0	0.0	0.03	0.52	0.65
Post	0.1762%	-0.0021%	-0.0018%	0.2317%	-0.0518%	-0.0017%	-0.0008%	0.0028%
	0.0	0.54	0.39	0.0	0.0	0.01	0.06	0.0
March 19								
Day	0.1220%	-0.0027%	0.0037%	0.1745%	-0.0490%	-0.0028%	-0.0038%	0.0022%
	0.0	0.29	0.02	0.0	0.0	0.0	0.02	0.0
Morning	0.1289%	-0.0021%	0.0030%	0.1814%	-0.0498%	-0.0022%	-0.0029%	0.0016%
	0.0	0.20	0.12	0.0	0.0	0.0	0.01	0.0
Pre	0.1717%	-0.0034%	0.0025%	0.2079%	-0.0330%	-0.0014%	-0.0022%	0.0014%
	0.0	0.32	0.03	0.0	0.0	0.02	0.03	0.03
Post	0.1398%	-0.0026%	0.0034%	0.1802%	-0.0362%	-0.0035%	-0.0024%	0.0011%
	0.0	0.50	0.01	0.0	0.0	0.02	0.04	0.23

The ask return CIRFs mirror the preceding results for the *Trade*, *Change to Existing Bid*, and *New Bid* impulses, but the effect sizes and direction by side of the market (bid or ask) are reversed (see Appendix 3.2). For example, the Ask Price Change acts as the mean reverting force for the

ask return CIRF, instead of the Bid Price Change, and the contribution of the *New Ask* is comparable to the contribution of *New Bid* in Table 3.5. Similar comparisons can be made for the other components of the ask return CIRFs, which exhibit the same pattern for bid return CIRF breakdowns for *Change to Existing Ask* and *New Ask* impulses (see Appendix 3.3). Comparing the results for the bid return and ask return CIRFs supports the conclusion that the market is largely symmetrical, with buying/selling interacting in the same way with the opposing passive offers/bids. In light of the demonstrated symmetry, I will focus on results for only the bid side of the market.

The process that causes the return CIRFs can be investigated through the order flow CIRFs arising from the same impulse. The order flow resulting from the initial shock may provide additional support for the return CIRF evidence. Table 3.6 provides the endogenous responses for the order flow variables for a 1,000 share *Trade* impulse that correspond to the bid return CIRFs in Table 3.2. The initial 1,000 share impulse has been removed from the *Trade* CIRF, so the trade volume shown in the *Trade* column for VAR Model 1 is only the follow-on trades induced by the initial trade impulse. The order flow information in Table 3.6 provides the rationale for the overestimation of the information in active trades, as per Mizrach (2008). The total absolute amount of trading volume (the sum of the absolute values of columns 2 through 6 in Table 3.6) in VAR Model 1 is approximately the same as for the *Trade* variable in Chapter 2 but is now spread across five order flow variables. The information content of active trades is overestimated because the *Trade* variable in the bivariate VAR model overestimates the trade response in the absence of other order flow variables.

Table 3.6: Order Flow CIRFs for 1,000 share *Trade*

This table reports the average order flow CIRFs for the VAR model from Chapter 2 in the *Standard* column (the only order flow variable is *Trade*), and the average order flows CIRFs for VAR Model 1 in columns 2 through 6 from a *Trade* impulse. The table presents only the endogenous order flow response from the *Trade* impulse. For example, the *Trade* order flow CIRF of 283 shares for the day of March 18th in column 2 does not include the initial 1,000 share *Trade* impulse and represents only the follow-on *Trade* activity. Similarly, the *Trade* impulse induces an average *Change to Existing Bid* response of 163 shares for the day subperiod on March 18th in column 3. Cross-listed and non-cross-listed subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Order Flow CIRFs for 1,000 Share Trade impulse - Cross-listed Stocks						
	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	712	283	163	51	-153	37
		0.0	0.0	0.0	0.0	0.0
Morning	669	289	142	52	-134	30
		0.0	0.0	0.0	0.0	0.0
Pre	382	200	164	12	-205	26
		0.0	0.0	0.73	0.0	0.17
Post	612	290	184	49	-156	41
		0.0	0.0	0.03	0.0	0.0
March 19						
Day	666	251	158	43	-164	34
		0.0	0.0	0.0	0.0	0.0
Morning	623	231	121	43	-128	22
		0.0	0.0	0.0	0.0	0.11
Pre	427	210	211	47	-199	39
		0.0	0.0	0.0	0.0	0.0
Post	488	265	204	37	-222	42
		0.0	0.0	0.0	0.0	0.0

Order Flow CIRFs for 1,000 Share Trade impulse – Non-Cross-listed Stocks						
	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	455	227	65	68	-19	49
		0.0	0.0	0.0	0.17	0.0
Morning	346	207	41	60	-33	65
		0.0	0.02	0.0	0.05	0.0
Pre	338	163	56	52	7	26
		0.0	0.0	0.0	0.74	0.12
Post	416	195	71	61	-24	39
		0.0	0.0	0.0	0.09	0.01
March 19						
Day	414	227	29	34	-67	50
		0.0	0.06	0.0	0.0	0.0
Morning	481	243	17	29	-82	54
		0.0	0.35	0.01	0.0	0.0
Pre	155	132	38	24	-53	19
		0.0	0.02	0.01	0.01	0.09
Post	288	147	28	31	-44	35
		0.0	0.07	0.0	0.08	0.0

Two important results stand out in Table 3.6. First, there is a larger passive order flow response for cross-listed stocks. Even though the passive order flow impacts the bid return in the same direction as the trade impulse, the added endogenous response for cross-listed stocks does not correct for the higher return CIRFs of non-cross-listed stocks (i.e. cross-listed stocks see more follow-on trading activity, but less resulting bid return CIRF). Second is the low passive order response in the non-cross-listed subgroup. Clearly, the mechanism of information impounding is different for these groups, as non-cross-listed stocks rely more heavily on the direct impact of

active trades while the cross-listed stocks have additional endogenous influence from the passive order flow.

The total amount of order flow is similar for VAR Model 1 and the VAR model from Chapter 2 (the first column in the table) that follows Hasbrouck (1991), but the order flow in VAR Model 1 is spread amongst multiple order flow variables. The VAR models are attributing some of the return CIRF to the endogenous response of the trading variables (i.e. the order flow resulting from the initial impulse contributes to the return CIRF). In the absence of any trading variable other than active trades, all of the endogenous trading activity in Hasbrouck's model is attributed to active trades. In VAR Model 1, this activity is now partly apportioned to the passive order flow. Although the total effect is the same (i.e. similar return CIRFs), we now have a better idea of the sources of the CIRFs. Information does not impound into prices solely through active trades.

The order flow impulse response to changes in the existing bid (Table 3.7) have a stronger endogenous response in the cross-listed subgroup than the non-cross-listed subgroup, which is counter to the response from the *Trade* impulse. In addition, cross-listed stocks treat the *Change to Existing Bid* as an informed trade, with endogenous order flow in the same direction as the *Change to Existing Bid* (i.e. the existing ask falls in size and ask prices rise when there is an increase in the size of the bid). The non-cross-listed subgroup, however, treats the *Change to Exiting Bid* as an uninformed trade, with the order flow on the ask side of the market moving in the opposite direction (i.e. the existing ask size increases and the ask price falls when there is an increase in the size of the bid). The contrast in results between Table 3.6 and Table 3.7 Table 3.may be due to the influence of US trading for the cross-listed stocks, with the US market acting as the lead in the same way as the New York Stock Exchange in Hasbrouck (1995).

Table 3.8 Table 3. illustrates another behavioral trait of the price discovery process, which is bid and offer volume flowing to the best bid or offer in the market. New bids experience a follow-on increase in their size, represented by the positive *Change to Exiting Bids*. As the bid return CIRF for *New Bids* has a strong mean reversion influence from bid price changes (after factoring in the

effect of ask price changes) the persistence of bid return CIRFs for *New Bids* may rest on the ability of this follow-on volume to resist the reversion pressure (i.e. the permanence of the price change is dependent on passive order flow absorbing the mean reverting endogenous price change). This paints a more complex picture of the permanent price impact process that requires us to look past the single CIRF return result typically reported; do permanent price changes require uninformed liquidity providers? The difference in cross-listed and non-cross-listed reaction to passive order flow in Table 3.7Table 3. is repeated in Table 3.8, with cross-listed stocks seeing the ask side of the market move in the direction of the *New Bid* while the non-cross-listed subgroup's ask side moves against the *New Bid*; cross-listed stocks treat the *New Bid* as informed while the non-cross-listed stocks treat the *New Bid* as uninformed.

Table 3.7: Order Flow CIRFs for 1,000 share *Change to Existing Bid*

The following table reports the average order flow CIRFs for the VAR model from Chapter 2 in the *Standard* column (the only order flow variable is *Trade*), and the average order flows CIRFs for VAR Model 1 in columns 2 through 6 from a *Change to Existing Bid* impulse. The table presents only the endogenous order flow response from the *Change to Existing Bid* impulse. For example, the *Change to Existing Bid* order flow CIRF of 221 shares for the day of March 18th in column 3 does not include the initial 1,000 share *Change to Existing Bid* impulse and represents only the follow-on *Change to Existing Bid* activity. Similarly, the *Change to Existing Bid* impulse induces an average *Trade* response of 46 shares for the day subperiod on March 18th in column 2. Cross-listed and non-cross-listed subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Order Flow CIRFs for 1,000 Share Change to Existing Bid impulse - Cross-listed Stocks

	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	712	46	221	83	-82	12
		0.0	0.0	0.0	0.0	0.06
Morning	669	48	245	91	-76	12
		0.0	0.0	0.0	0.0	0.01
Pre	382	51	313	81	-90	12
		0.0	0.0	0.0	0.0	0.04
Post	612	47	180	79	-104	25
		0.0	0.0	0.0	0.0	0.0
March 19						
Day	666	29	270	77	-94	13
		0.0	0.0	0.0	0.0	0.09
Morning	623	32	282	103	-68	6
		0.0	0.0	0.0	0.0	0.52
Pre	427	27	238	61	-99	19
		0.01	0.0	0.0	0.0	0.0
Post	488	33	287	63	-122	18
		0.0	0.0	0.0	0.0	0.01

Order Flow CIRFs for 1,000 Share Change to Existing Bid impulse – Non-Cross-listed Stocks						
	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day		90	195	269	115	-54
	455	0.02	0.0	0.0	0.0	0.0
Morning		-8	167	316	87	-66
	346	0.86	0.0	0.0	0.0	0.0
Pre		97	51	170	102	-50
	338	0.0	0.0	0.0	0.02	0.07
Post		85	119	189	97	-25
	416	0.01	0.0	0.0	0.0	0.10
March 19						
Day		-5	159	239	170	-111
	414	0.86	0.0	0.0	0.0	0.0
Morning		-26	104	258	116	-115
	481	0.51	0.0	0.0	0.0	0.0
Pre		35	55	118	141	-80
	155	0.17	0.0	0.0	0.0	0.0
Post		-33	189	162	176	-75
	288	0.39	0.0	0.0	0.0	0.0

Table 3.8: Order Flow CIRFs for 1,000 share *New Bid*

The table below reports the average order flow CIRFs for the VAR model from Chapter 2 in the *Standard* column (the only order flow variable is *Trade*), and the average order flows CIRFs for VAR Model 1 in columns 2 through 6 from a *New Bid* impulse. The table presents only the endogenous order flow response from the *New Bid* impulse. For example, the *New Bid* order flow CIRF of -17 shares (i.e. 17 shares sold) for the day of March 18th in column 4 does not include the initial 1,000 share *New Bid* impulse and represents only the follow-on *New Bid* activity. Similarly, the *New Bid* impulse induces an average *Trade* response of 3 shares for the day subperiod on March 18th in column 2. Cross-listed and non-cross-listed subgroup results are presented in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Order Flow CIRFs for 1,000 Share New Bid impulse - Cross-listed Stocks						
	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	712	3	401	-17	-88	40
		0.75	0.0	0.64	0.0	0.0
Morning	669	20	396	-30	-48	40
		0.13	0.0	0.37	0.02	0.01
Pre	382	-55	564	-30	-203	48
		0.32	0.0	0.54	0.0	0.0
Post	612	-2	404	-27	-108	47
		0.86	0.0	0.45	0.0	0.0
March 19						
Day	666	-24	425	-45	-92	26
		0.02	0.0	0.10	0.0	0.0
Morning	623	-20	322	-44	-53	20
		0.11	0.0	0.08	0.01	0.01
Pre	427	-23	639	-68	-170	49
		0.23	0.0	0.05	0.0	0.0
Post	488	-47	619	-65	-174	50
		0.02	0.0	0.04	0.0	0.0

Order Flow CIRFs for 1,000 Share New Bid impulse – Non-Cross-listed Stocks						
	Standard	VAR Model 1				
March 18	Trade	Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day		-18	361	182	95	-28
	455	0.38	0.0	0.0	0.0	0.02
Morning		-21	309	208	114	-49
	346	0.59	0.0	0.0	0.01	0.04
Pre		15	376	34	139	-20
	338	0.71	0.0	0.33	0.06	0.26
Post		15	372	89	76	-11
	416	0.65	0.0	0.01	0.0	0.46
March 19						
Day		-21	334	169	120	-84
	414	0.63	0.0	0.03	0.0	0.0
Morning		23	239	165	111	-94
	481	0.53	0.0	0.03	0.0	0.0
Pre		-86	313	41	58	-65
	155	0.27	0.0	0.30	0.38	0.05
Post		-27	462	33	157	-40
	288	0.73	0.0	0.46	0.0	0.03

Granger Causality and Instantaneous Causality test p-values are presented in Appendix 3.4, along with a brief discussion of their applicability to the VAR models in this Chapter. The complex interrelationships in the VAR model make it difficult to apply standard diagnostic tests (Stock and Watson, 2001), with Granger Causality tests commonly used in lieu of R^2 or F-Tests. There are a number of problems with relying too heavily on the Granger test results, however, although they may provide some weak information about the explanatory power of the variables.

3.4.1.1 VAR Model 1 Summary

Trade

The trade variable CIRFs agree broadly with the adverse selection/informed trading and information clustering literature. We see positive return CIRFs for trade impulses, indicating a permanent price change and information impounding stem from trading, and this is not dissipated by the presence of passive order information. The return CIRFs are higher during the morning subperiods and post subperiod on March 18 than in the subperiods where we would not expect the market to be processing new information (pre subperiods and post subperiod on

March 19). The two subgroups, however, have different reactions for bid and ask return CIRFs and passive order flow. *Trades i*n the cross-listed subgroup have the same or greater effect on ask prices as bid prices, meaning that trades tend to widen the spread in accordance with an increased risk from adverse selection. In the non-cross-listed subgroup the opposite occurs, where the bid-ask spread tightens after a trade. This is curious as it suggests that the non-cross-listed subgroup views the trade as being uninformed. Similar, but weaker, evidence is provided by the lower passive order response to a trade impulse in the non-cross-listed subgroup where it appears less important for passive orders to adjust to trade innovations. The obvious distinction between the subgroups is the presence or absence of cross-border arbitrage orders bringing the other market's liquidity to the TSX. It should be concerning that the additional liquidity of a cross-listing apparently makes active trades look more informed to the VAR model, as these stocks tend to be larger and more liquid and are more likely to be used in the data sets in the literature and the VAR model may be measuring liquidity instead of information.

Change to Existing Bid/Ask

The passive order flow mechanism for impounding information is different than that of active trades. Bid and ask return CIRFs are caused more by the knock-on effect of a change in an existing bid or ask, the subsequent *New Bid* or *Ask*, than directly by the change in the bid or ask. This is a unique result for the information impounding literature, as it suggests that indirect effects can dominate the direct impact of trading activity on prices, or that sequences of variables may be more important than individual observations. Certain sequences of orders, such as changes in an existing bid followed by a *New Bid*, may have more impact than others, such as a *New Bid* followed by a change in an existing bid. In this case, perhaps we should treat combinations of orders as a single variable, such as a *Change to Existing Bid* immediately after a *New Bid* variable distinct from a *Change to Existing Bid* not immediately preceded by a *New Bid* (i.e. orders are not independent, but are constituents of a package and it is the package that causes price changes).

Even though the return CIRFs for both subgroups experience more indirect influence from *New Bids*, the mechanism at work is different. Cross-listed stocks, as we saw with trade, treat the *Change to Exiting Bids*/*Asks* as informed, with the opposite side of the market moving in sympathy (i.e. existing ask sizes fall and *New Asks* prices rise). The non-cross-listed group continues to treat order flow as uninformed, with the opposite of the market trading against the change in bid or ask (i.e. existing ask sizes rise and *New Ask* prices fall and endogenous trading activity is negative in half the subperiods). Again, this difference may be due to cross-listing arbitrage trading in the cross-listed subgroup.

The return CIRFs are notably smaller for changes in existing bids or asks than for trades. This result is also found by Brogaard et al. (2019) and Fleming et al. (2018) who note that a larger number of passive orders could result in a similar overall effect, despite the passive order having a small impact on a share-for-share basis. This conclusion may hold for the cross-listed subgroup, which has substantially more passive order than active trading activity, but is not the case for the non-cross-listed subgroup (Table 3.9). A more general takeaway is that the non-cross-listed return CIRFs are higher than the cross-listed returns CIRFs, across than board, and that the result for the non-cross-listed subgroup would not be mitigated by differences in trading activity across order category.

Table 3.9: Average Number of Observations

The table below presents the average number of observations for each variable in VAR Model 1, broken down by subperiod and with cross-listed and non-cross-listed stock data reported in separate panels. There are, for example, an average of 8,471 *Trade* observations in the day subperiod of March 18th for the cross-listed subgroup.

	Cross-listed Stocks						
March 18	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
Day	8,471	34,149	5,580	7,123	36,312	5,739	7,329
Morning	2,955	11,541	1,815	2,390	14,778	2,119	2,693
Pre	1,395	8,346	749	998	8,295	778	1,037
Post	4,121	14,262	3,016	3,735	13,238	2,842	3,599
March 19							
Day	7,215	34,827	4,628	5,856	36,860	4,462	5,695
Morning	3,858	16,714	2,677	3,385	17,075	2,611	3,334
Pre	1,606	10,413	1,068	1,331	9,657	954	1,216
Post	1,751	7,701	883	1,140	10,128	898	1,145

	Non-Cross-listed Stocks						
March 18	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
Day	1,586	2,988	1,298	1,646	2,286	1,165	1,541
Morning	611	999	624	770	963	584	736
Pre	331	826	213	282	594	204	279
Post	643	1,162	461	593	729	377	525
March 19							
Day	1,514	2,103	1,162	1,497	2,373	1,182	1,548
Morning	727	1,109	691	859	1,069	660	843
Pre	354	476	250	331	775	293	383
Post	433	518	221	308	529	229	322

New Bid/Ask

The return CIRFs for *New Bids* and asks are larger than for any other variable. Since every *New Bid* or *Ask*, by definition, causes a change in the bid or ask price, this might seem trivial. The return CIRFs, however, are the net return over 100 ticks, so the return CIRFs attributable to *New Bids* and asks are persistent and do not represent a momentary shock to the NBBO quotes. The persistence of the price impact is likely related to the *Change to Exiting Bid* and ask response, which shows passive orders joining the *New Bid* and *Ask*. It may not be the *New Bid* or *Ask* that is affecting prices, but the combination of the *New Bid* or *Ask* and the subsequent change in the bid or ask size at the new price set by the *New Bid* or *Ask*.

Perhaps because of this apparent tie between new and existing bids and asks, the results for *New Bids* and asks mirror those from changes in existing bids and asks. Active trades largely treat the *New Bid* or *Ask* as uninformed, trading against *New Bids* (selling) and asks (buying), and the opposite side of the market for cross-listed stocks behaves as though the *New Bid* is informed (i.e. ask sizes fall and ask prices rise after a *New Bid*), while the non-cross-listed side treats *New Bids* and asks as uninformed (i.e. ask size increases and ask prices fall). The subgroup differences may be caused by liquidity seeking behavior overwhelming the information conveyed by the *New Bid* or *Ask*. Traders executing in the cross-listed subgroup do not have the same worries about finding liquidity and can focus on the information content of orders, while the non-cross-listed

subgroups may preference liquidity over information and intentionally trade against information to find liquidity.

The informed trading literature has generally concluded that passive orders represent uninformed trading, while active orders incorporate information. If this is the case, why do *New Bids* and asks, which are passive orders, generate higher return CIRFs than active trades? Additionally, *New Bids* and asks cause larger reductions in the bid-ask spread than trades, which further confuses the adverse selection interpretation. From the literature, the reduced spread should indicate reduced risk of adverse selection, which is contrary to the larger return CIRFs. The bid-ask spread impact is over 100 ticks, so the market is simultaneously accepting the seemingly contradictory lower spread and higher price impact.

3.4.1.2 VAR Model 1 Conclusions

The granular analysis of the VAR Model 1 results, and the components that drive the CIRFs, uncover the complex interplay between the different types of order flow that contribute to the CIRFs. The largest influence on the CIRFs is the initial impulse, which is an exogenous shock with unknown origin, leaving us with the market's reaction to that shock as the pattern we use to calculate the information content of the shock. This produces contradictory interpretations of the information content of the initial impulse when look beyond the CIRFs and consider the components of the CIRFs, which may conform to an informed or uninformed market reaction to the initial impulse. If we believe the market does a reasonable job of inferring the information content of an impulse, the CIRF component analysis may be a better information guide than the CIRFs.

Differences between the subgroups may be due to cross-border arbitrage. Accessing additional liquidity in the US market could explain the lower return CIRFs in the cross-listed subgroup. The order flow response, however, provides an interesting frame of comparison. The response of the ask side of the market to order flow on the bid is opposite in sign between the two subgroups.

For the cross-listed subgroup, the ask side behaves as if the bid order flow is informed, adjusting upwards in response, while the non-cross-listed subgroup treats bidding activity as uninformed, adjusting downwards. Cross-border arbitrage trades may be the answer, as they would react in unison to changes in the Canadian dollar prices of the US NBBO; the trading may be less informed than it appears, as changes in the US market act to co-ordinate passive order flow in Canada.

3.4.2: VAR Model 2

VAR Model 2 differs from VAR Model 1 by splitting the trades into *Inflection* and *Non-Inflection* trades, as described in the data section. The distinction is between the first trade in a sequence (*Inflection* trades) or trades other than the first in a sequence (*Non-Inflection* trades). In some cases the trading sequence is only one trade in length and is solely composed of *Inflection* trades. Table 3.10 shows the average number of observations for *Inflection* and *Non-Inflection* trades and the ratio of the average number of observations. For the cross-listed subgroup, an *Inflection* trade is followed by an average of 2.4 to 2.8 *Non-Inflection* trades (i.e. the average sequence of positively serially correlated trades is between 3.4 to 3.8), with a range near or below 2 for the non-cross-listed subgroup, as shown in the Ratio of *Trades* columns. The higher return CIRFs for the non-cross-listed subgroup in Table 3.2 are not attributable to longer trading runs, reinforcing the difference in the information content of individual trades and market responses between the two subgroups.

Table 3.10: Average Number of *Inflection* and *Non-Inflection* Trade Observations

This table reports the average number of *Inflection* and *Non-Inflection* trade observations in VAR Model 2, broken down by subperiod and subgroup. The sum of the *Inflection* and *Non-Inflection* trades in this table equal the number of *Trade* observations in Table 3.9 for the same subperiod and subgroup. There are, for example, an average of 2,355 *Inflection* trades and 6,116 *Non-Inflection* trades for the day of March 18th in the cross-listed subgroup, totalling the 8,471 *Trade* observations for cross-listed subgroup during the day subperiod of March 18th in Table 3.9.

	Cross-Listed Stocks			**Non-Cross-Listed Stocks**		
March 18	Inflection Trades	Non-Inflection Trades	Ratio of Trades	Inflection Trades	Non-Inflection Trades	Ratio of Trades
Day	2,355	6,116	2.6	516	1,069	2.1
Morning	854	2,101	2.5	202	410	2.0
Pre	409	985	2.4	107	224	2.1
Post	1,091	3,030	2.8	208	435	2.1

March 19						
Day	1,973	5,243	2.7	522	992	1.9
Morning	1,074	2,784	2.6	241	487	2.0
Pre	441	1,166	2.6	131	223	1.7
Post	458	1,293	2.8	150	283	1.9

The return CIRFs for the new *Inflection* and *Non-Inflection* trading variables are presented in Table 3.11. The CIRF results for VAR Model 2 do not materially change for the passive order flow variables and their results will be presented in Appendix 3.5, along with the data in Table 3.11. The return CIRFs are similar for *Inflection* and *Non-Inflection* trades, with the same difference in results between subgroups observed for VAR Model 1, that the non-cross-listed subgroup has higher return CIRFs, with a mix of *Inflection* or *Non-Inflection* trades producing higher return CIRFs. Considering Tables 3.10 and 3.11 together suggests that momentum is not a contributor to price formation since the non-cross-listed subgroup has higher return CIRFs with lower average *Non-Inflection* trade sequence length. Both subgroups show a lack of dominance for either *Inflection* or *Non-Inflection* trade return CIRFs, despite having the difference in the length of the trading sequences in the subgroups. If the Jegadeesh and Titman (1993) concept of momentum, that winners continue to win, is true at the tick level, we should observe an impact from longer trading sequences on prices.

An analogous conclusion is that the first trade in a sequence contains the same information as subsequent trades in a sequence, given the similarities in the return CIRFs. If this is true, the predictive value of the historical sequence is questionable. The first trade in a sequence does not define a trend, but the market places the same weight on the potential for a new trend as on the trades that reinforces the existence of a trend (i.e. the second, third, fourth, etc., trade in a sequence). Does this mean that an information measure like VAR that relies on sequential patterns will not be able to distinguish between informed and uninformed trades since every trade looks the same; there is only one pattern to find as determined by the first trade in a sequence. This would mean all trades are informed or uninformed, but should a mean reverting trade working against a permanent price change be as informative as trade that could lead to a permanent price change? If so, the information being measured is closer to the contrarian

strategy definition of an informed trader taking advantage of temporary illiquidity than the informed trader identified by Kyle (1985).

Inflection trades are always the first trade in the sequence, and therefore have the maximum amount of follow-on positive serial correlation from *Non-Inflection* trades. Since the VAR model estimates what happens next, the *Inflection* trades contain all of the information of the *Non-Inflection* trades. The opposite is not true, however, as the *Non-Inflection* trades are always missing the first trade in a sequence and are always one trade closer to the end of the sequence. An average sequence length is 3 to 4 trades, which means removing the first trade of a sequence removes a quarter to a third of the sequence, but more than quarter to a third of its information. From an information measurement perspective, the sequence of *Inflection* trades may be more important than the *Non-Inflection* trades as the *Inflection* trades contain a disproportionately large amount of the information in a trading sequence.

Table 3.11: Return CIRFs for *Inflection* and *Non-Inflection* Trade Impulses

The table below presents the average bid and ask return CIRFs for *Inflection* trade and *Non-Inflection* trade impulses, broken down by subperiod and subgroup. Column 3, for example, reports an average bid return CIRF of 0.064% for an *Inflection* trade impulse in the day subperiod of March 18th for cross-listed stocks. The corresponding ask return CIRF is 0.069%. Average return CIRFs for *Non-Inflection* trade impulses are presented in columns 3 and 6 for cross-listed and non-cross-listed stocks, respectively. Midpoint price changes for each subperiod and subgroup are included in columns 1 and 4 for reference. P-values are presented below each table entry for a two-tailed T-Test of a null hypothesis that the average return CIRF equals 0.

	Cross-Listed Stocks			Non-Cross-Listed Stocks		
March 18	Midpoint % Change	Inflection Trade Impulse	Non-Inflection Trade Impulse	Midpoint % Change	Inflection Trade Impulse	Non-Inflection Trade Impulse
Day	2.133%	0.064%	0.068%	1.319%	0.097%	0.082%
		0.0	0.0		0.0	0.0
		0.069%	0.081%		0.075%	0.079%
		0.0	0.0		0.0	0.0
Morning	-0.782%	0.065%	0.082%	-0.849%	0.112%	0.089%
		0.0	0.0		0.0	0.0
		0.062%	0.082%		0.087%	0.076%
		0.0	0.0		0.0	0.0
Pre	0.686%	0.053%	0.056%	0.779%	0.062%	0.054%
		0.0	0.0		0.0	0.0
		0.075%	0.076%		0.054%	0.058%
		0.01	0.0		0.0	0.0
Post	2.244%	0.072%	0.070%	1.411%	0.092%	0.086%
		0.0	0.0		0.0	0.0
		0.068%	0.085%		0.067%	0.086%
		0.0	0.0		0.0	0.0

March 19						
Day	-0.741%	0.045%	0.051%	-1.713%	0.074%	0.082%
		0.0	0.0		0.0	0.0
		0.048%	0.051%		0.065%	0.075%
		0.0	0.0		0.0	0.0
Morning	-0.417%	0.055%	0.069%	-1.075%	0.091%	0.098%
		0.0	0.0		0.0	0.0
		0.066%	0.072%		0.085%	0.084%
		0.0	0.0		0.0	0.0
Pre	0.344%	0.048%	0.044%	-0.297%	0.077%	0.083%
		0.0	0.0		0.0	0.0
		0.044%	0.044%		0.068%	0.082%
		0.0	0.0		0.0	0.0
Post	-0.667%	0.035%	0.033%	-0.354%	0.051%	0.052%
		0.0	0.0		0.0	0.0
		0.037%	0.037%		0.049%	0.055%
		0.0	0.0		0.0	0.0

The return CIRF components in Tables 3.12 and 3.13 Table 3. highlight an interesting distinction between *Inflection* and *Non-Inflection* trade mechanisms (only the *Inflection* and *Non-Inflection* components are presented in Tables 3.12 and 3.13, the full results for all components are included in Appendix 3.6). After an *Inflection* trade, both *Inflection* and *Non-Inflection* trades contribute to the return CIRF in the same direction (e.g. columns 2 and 3 in Table 3.12). In the case of a *Non-Inflection* trade, the return CIRF is inhibited by follow-on *Inflection* trades (column 2 in Table 3.13). The *Inflection* trade impulse overcomes the subsequent *Inflection* trades in the 100-tick forecast period, but not the *Non-Inflection* trades; the *Inflection* trade is sending a more informative signal to the market than a *Non-Inflection* trade. The *Inflection* trade is acting as a stronger signal of the subsequent trading trend than a trade that is already part of an existing trend. The *Inflection* trade, being a trade that by definition is reverting to the mean, faces less mean reverting force than the *Non-Inflection* trade. Established trading sequences encounter more counter-sequence activity, suggesting the market is predicting the sequence's demise. If the market viewed the *Non-Inflection* trades as containing more information due to their sequential nature, there should be less predicted resistance to those *Non-Inflection* trades.

When there is a single trade variable, as in VAR Model 1, the different mechanics operating on the return CIRF (i.e. the components that produce the return CIRF) are consolidated and obscure the internal workings of the market, as estimated by the bivariate VAR model. Splitting the trades

splits the components that feed into the return CIRF, which isolates the difference in contributions from different trading patterns.

Table 3.12: Bid Return CIRF breakdown for 1,000 share *Inflection* Trade Impulse

This table presents the *Inflection* and *Non-Inflection* components of the average bid return CIRFs for VAR Model 2 from an *Inflection* trade impulse (the bid return CIRFs from columns 2 and 5 in Table 3.11) over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Inflection* and *Non-Inflection* trades presented in columns 2 and 3, respectively. Differences between column 1 and the sum of columns 2 and 3 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.064%, with *Inflection* trades contributing 0.057% and *Non-Inflection* trades contributing 0.017% (the difference of -0.010% between 0.064% and total *Inflection* and *Non-Inflection* trade contribution of 0.074% is attributable to the omitted variables). The *Inflection* trade contribution includes the exogenous *Inflection* trade impulse, but the *Non-Inflection* trade contribution is solely due to its endogenous response. Analogous results for non-cross-listed stocks are reported in columns 4 through 6. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks			**Non-Cross-Listed Stocks**		
	CIRF	by Inflection	by Non-Inflection	CIRF	by Inflection	by Non-Inflection
March 18		Trade	Trade		Trade	Trade
Day	0.064%	0.057%	0.017%	0.097%	0.090%	0.019%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.065%	0.056%	0.021%	0.112%	0.101%	0.026%
	0.0	0.0	0.02	0.0	0.0	0.04
Pre	0.053%	0.047%	0.010%	0.062%	0.056%	0.006%
	0.0	0.0	0.0	0.0	0.0	0.0
Post	0.072%	0.074%	0.010%	0.092%	0.091%	0.014%
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	0.045%	0.038%	0.009%	0.074%	0.062%	0.027%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.055%	0.043%	0.015%	0.091%	0.076%	0.033%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.048%	0.045%	0.008%	0.077%	0.064%	0.019%
	0.0	0.0	0.0	0.0	0.0	0.0
Post	0.035%	0.029%	0.005%	0.051%	0.049%	0.010%
	0.0	0.0	0.01	0.0	0.0	0.0

Table 3.13: Bid Return CIRF breakdown for 1,000 share *Non-Inflection* Trade Impulse

This table reports the *Inflection* and *Non-Inflection* components of the average bid return CIRFs for VAR Model 2 from a *Non-Inflection* trade impulse (the bid return CIRFs from columns 3 and 6 in Table 3.11) over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Inflection* and *Non-Inflection* trades presented in columns 2 and 3, respectively. Differences between column 1 and the sum of columns 2 and 3 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.068%, with *Inflection* trades contributing -0.006% and *Non-Inflection* trades contributing 0.083% (the difference of -0.0144% between 0.068% and total

Inflection and *Non-Inflection* trade contribution of 0.0824% is attributable to the omitted variables). The *Non-Inflection* trade contribution includes the exogenous *Non-Inflection* trade impulse, but the *Inflection* trade contribution is solely due to its endogenous response. Analogous results for non-cross-listed stocks are reported in columns 4 through 6. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks			**Non-Cross-Listed Stocks**		
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	CIRF	by Inflection Trade	by Non-Inflection Trade
Day	0.068%	-0.006%	0.083%	0.082%	-0.009%	0.095%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.082%	-0.005%	0.100%	0.089%	-0.009%	0.108%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.056%	-0.004%	0.056%	0.054%	-0.004%	0.058%
	0.0	0.0	0.0	0.0	0.0	0.0
Post	0.070%	-0.006%	0.084%	0.086%	-0.007%	0.098%
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	0.051%	-0.003%	0.055%	0.082%	-0.006%	0.102%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.069%	-0.003%	0.078%	0.098%	-0.006%	0.122%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.044%	-0.005%	0.047%	0.083%	-0.006%	0.096%
	0.0	0.05	0.0	0.0	0.0	0.0
Post	0.033%	-0.003%	0.035%	0.052%	-0.005%	0.059%
	0.0	0.0	0.0	0.0	0.0	0.0

The *Inflection* and *Non-Inflection* trade impacts on the return CIRF from to a *Change to Existing Bid* impulses (Table 3.14) have a similar pattern to the *Inflection* trade impulse in Table 3.12. Analogously, the contribution pattern of *Inflection* and *Non-Inflection* trades to the return CIRF due to a *New Bid* impulse (Table 3.15) have the same pattern as the *Non-Inflection* trade impulse in Table 3.13 (full results are presented in Appendix 3.7). By trading with the *Change to Existing Bid*, the active trades are interpreting the passive order flow as informed, despite not directly changing the price. This may be in anticipation of the *New Bid* reaction to changes in the existing bid. *New Bids*, however, are viewed as being uninformed with *Inflection* trades working against the *New Bid* return CIRF. The difference in reaction reinforces the idea that the market may be interpreting some packages of orders (i.e. *Change to Exiting Bids* followed by *New Bids*) as containing information, while the same constituents in a different package (i.e. *New Bids* followed by a *Change to Existing Bid*) are not interpreted as conveying information.

Table 3.14: Bid Return CIRF breakdown for 1,000 share *Change to Existing Bid*

The table below presents the *Inflection* and *Non-Inflection* components of the average bid return CIRFs for VAR Model 2 from a *Change to Existing Bid* impulse over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Inflection* and *Non-Inflection* trades presented in columns 2 and 3, respectively. Differences between column 1 and the sum of columns 2 and 3 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.021%, with *Inflection* trades contributing -0.001% and *Non-Inflection* trades contributing 0.002% (the difference of 0.020% between 0.021% and total *Inflection* and *Non-Inflection* trade contribution of 0.001% is attributable to the omitted variables). Both the *Inflection* and *Non-Inflection* trade contributions are solely due to their endogenous response. Analogous results for non-cross-listed stocks are reported in columns 4 through 6. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks			**Non-Cross-Listed Stocks**		
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	CIRF	by Inflection Trade	by Non-Inflection Trade
Day	0.021%	-0.001%	0.002%	0.041%	-0.003%	0.007%
	0.0	0.28	0.0	0.0	0.0	0.0
Morning	0.018%	0.000%	0.002%	0.045%	-0.003%	0.003%
	0.0	0.40	0.0	0.0	0.0	0.34
Pre	0.017%	0.000%	0.001%	0.024%	-0.001%	0.004%
	0.0	0.35	0.23	0.0	0.12	0.02
Post	0.022%	0.000%	0.002%	0.030%	-0.003%	0.007%
	0.0	0.40	0.0	0.0	0.0	0.05
March 19						
Day	0.015%	0.000%	0.001%	0.031%	-0.003%	-0.002%
	0.0	0.09	0.04	0.0	0.04	0.73
Morning	0.022%	0.000%	0.002%	0.035%	-0.001%	-0.004%
	0.0	0.34	0.03	0.0	0.24	0.33
Pre	0.011%	-0.001%	0.000%	0.023%	-0.003%	0.001%
	0.0	0.29	0.32	0.0	0.02	0.63
Post	0.010%	0.000%	0.001%	0.020%	-0.003%	-0.002%
	0.0	0.58	0.01	0.0	0.04	0.49

Table 3.15: Bid Return CIRF breakdown for 1,000 share *New Bid*

The table below presents the *Inflection* and *Non-Inflection* components of the average bid return CIRFs for VAR Model 2 from a *New Bid* impulse over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Inflection* and *Non-Inflection* trades presented in columns 2 and 3, respectively. Differences between column 1 and the sum of columns 2 and 3 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.094%, with *Inflection* trades contributing -0.001% and *Non-Inflection* trades contributing 0.002% (the difference of 0.093% between 0.094% and total *Inflection* and *Non-Inflection* trade contribution of 0.001% is attributable to the omitted variables). Both the *Inflection* and *Non-Inflection* trade contributions are solely due to their endogenous response. Analogous results for non-cross-listed stocks are reported in columns 4 through 6. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks			Non-Cross-Listed Stocks		
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	CIRF	by Inflection Trade	by Non-Inflection Trade
Day	0.094%	-0.001%	0.002%	0.148%	-0.003%	0.001%
	0.0	0.0	0.17	0.0	0.0	0.70
Morning	0.114%	-0.002%	0.001%	0.161%	-0.003%	-0.001%
	0.0	0.01	0.15	0.0	0.01	0.72
Pre	0.116%	-0.001%	0.001%	0.148%	-0.002%	0.002%
	0.0	0.03	0.65	0.0	0.0	0.09
Post	0.098%	-0.001%	0.001%	0.176%	-0.004%	0.000%
	0.0	0.0	0.10	0.0	0.04	0.95
March 19						
Day	0.086%	-0.001%	0.000%	0.123%	-0.002%	-0.001%
	0.0	0.0	0.42	0.0	0.0	0.57
Morning	0.102%	-0.001%	0.001%	0.129%	-0.003%	-0.001%
	0.0	0.0	0.20	0.0	0.05	0.42
Pre	0.097%	-0.001%	-0.001%	0.169%	-0.002%	0.000%
	0.0	0.05	0.47	0.0	0.0	0.84
Post	0.090%	-0.001%	0.000%	0.142%	-0.002%	-0.003%
	0.0	0.01	0.67	0.0	0.15	0.43

The order flow CIRFs in Tables 3.16 and 3.17 (*Inflection* and *Non-Inflection* responses are presented, with full results in Appendix 3.8, as passive order flow results are similar to VAR Model 1) show a different picture of the trading activity than VAR Model 1 and the *Trade* CIRFs in Chapter 2. The inclusion of *Inflection* and *Non-Inflection* trades report effects that were previously ascribed to the *Trade* variable in VAR Model 1. For both *Inflection* and *Non-Inflection* trade impulses there is more endogenous active trading activity than in VAR Model 1 (the absolute sum of the *Inflection* and *Non-Inflection* columns in Tables 3.16 and 3.17 exceed the trading volumes in Table 3.6), with the *Inflection* (*Non-Inflection*) trade CIRFs trading in opposite (same) direction to the impulses. The prior trade CIRF in VAR Model 1 was netting out the *Inflection* and *Non-Inflection* trades, which masked some of the ebb and flow of trading activity that lead to the same return CIRFs; splitting the trades reveals a greater degree of "work" put in by the market in the price discovery process.

Net endogenous trading activity (*Inflection* plus *Non-Inflection* trade volumes) is higher for *Non-Inflection* than *Inflection* trades, but both trade impulses result in similar return CIRFs. This reinforces the idea that the information content of an *Inflection* trade exceeds that of a *Non-Inflection* trade, as the *Inflection* trade return CIRF is the result of less endogenous order flow for the same initial trade impulse; either the initial *Inflection* trade impulse is stronger than the *Non-*

Inflection trade impulse, or there is a different content to the endogenous order flow stemming from each type of trade impulse.

Table 3.16: Order Flow CIRFs for 1,000 share *Inflection* Trade

This table reports the average *Inflection* and *Non-Inflection* trade order flow CIRFs for VAR Model 2 from an *Inflection* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Inflection* trade impulse. For example, the *Inflection* trade order flow CIRF of -127 shares (i.e. sell of 127 shares) for the day of March 18th for cross-listed stocks in column 1 does not include the initial 1,000 share *Inflection* trade impulse and represents only the follow-on *Inflection* trade activity. The *Non-Inflection* trade CIRFs in columns 2 and 4 are solely the result of their endogenous responses, for cross-listed and non-cross-listed subgroups, respectively. For example, the *Inflection* trade impulse induces an average *Non-Inflection* trade response of 255 shares for the day subperiod on March 18th in column 2 for cross-listed shares, entirely endogenously. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks		**Non-Cross-Listed Stocks**	
March 18	Inflection Trade	Non-Inflection Trade	Inflection Trade	Non-Inflection Trade
Day	-127	255	-115	247
	0.0	0.0	0.0	0.0
Morning	-121	260	-111	216
	0.0	0.0	0.0	0.0
Pre	-114	229	-83	158
	0.0	0.0	0.0	0.0
Post	-119	236	-90	195
	0.0	0.0	0.0	0.0
March 19				
Day	-93	204	-107	298
	0.0	0.0	0.0	0.0
Morning	-97	197	-114	290
	0.0	0.0	0.0	0.0
Pre	-89	194	-124	348
	0.0	0.0	0.0	0.0
Post	-87	226	-72	204
	0.0	0.0	0.0	0.0

Table 3.17: Order Flow CIRFs for 1,000 share *Non-Inflection* Trade

This table reports the average *Inflection* and *Non-Inflection* trade order flow CIRFs for VAR Model 2 from a *Non-Inflection* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Non-Inflection* trade impulse. For example, the *Non-Inflection* trade order flow CIRF of 470 shares for the day of March 18th for cross-listed stocks in column 2 does not include the initial 1,000 share *Non-Inflection* trade impulse and represents only the follow-on *Non-Inflection* trade activity. The *Inflection* trade CIRFs in columns 1 and 3 are solely the result of their endogenous responses, for cross-listed and non-cross-listed subgroups, respectively. For example, the *Non-Inflection* trade impulse induces an average *Inflection* trade response of -81 shares (i.e. sell of 81 shares) for the day subperiod on March 18th in column 1 for cross-listed shares, endogenously. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks		Non-Cross-Listed Stocks	
March 18	Inflection Trade	Non-Inflection Trade	Inflection Trade	Non-Inflection Trade
Day	-81	470	-75	388
	0.0	0.0	0.0	0.0
Morning	-75	458	-69	307
	0.0	0.0	0.0	0.0
Pre	-80	338	-61	279
	0.0	0.0	0.0	0.0
Post	-78	478	-56	313
	0.0	0.0	0.0	0.0
March 19				
Day	-61	403	-81	337
	0.0	0.0	0.0	0.0
Morning	-61	383	-67	345
	0.0	0.0	0.0	0.0
Pre	-60	371	-77	210
	0.0	0.0	0.0	0.0
Post	-67	409	-92	253
	0.0	0.0	0.0	0.0

The CIRFs for *Change to Existing Bid* and *New Bid* impulses are in Tables 3.18 and 3.19 (full results in Appendix 3.9) show an interesting set of market mechanics with additional insight into the information content of the order flow. *Change to Existing Bid* and *New Bid* impulses produce similar differences in their endogenous trading patterns to *Inflection* and *Non-Inflection* trades. *Change to Existing Bid* spawns more *Non-Inflection* relative to *Inflection* trades, like the *Non-Inflection* trade impulse, while the *New Bid* impulse spawns a higher proportion of *Inflection* trades. It appears that active trades treat changes in the size of the volume at the prevailing bid price as being information while bids at new prices attract selling, suggesting that the market is discounting the price information in the *New Bid*, seeking to sell to better priced liquidity instead. It is not coded in the data, but the different reactions to the passive order impulses may be due to their timing in the trade sequence. If *New Bids* tend to occur near the beginning or end of a trend, they would more likely relate to *Inflection* trades, while Changes to Existing bids in the middle of a trading sequence would correspond more closely to *Non-Inflection* trades.

If the informed trading signals for the cross-listed stocks is caused by the order book in the US market, the information content of the passive orders may be more about the liquidity in the US market than any anticipated price changes in Canada. In this case, the “pure” order flow of the non-cross-listed stocks would be better indications of the information content of passive order flow, which would be liquidity seeking or uninformed. Given the amount of market

fragmentation, and prevalence of cross-listing of some kind for large capitalization stocks, this result calls into question conclusions that passive order flow is informed.

Table 3.18: Order Flow CIRFs for 1,000 share *Change to Existing Bid*

This table reports the average *Inflection* and *Non-Inflection* trade order flow CIRFs for VAR Model 2 from a *Change to Existing Bid* impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Change to Existing Bid* impulse. For example, the *Inflection* trade order flow CIRF of -8 shares (i.e. sell 8 shares) and *Non-Inflection* trade order flow CIRF of 56 shares for the day of March 18th for cross-listed stocks in columns 1 and 2, respectively, are solely the result of their endogenous responses. *Inflection* and *Non-Inflection* trade order flow CIRFs for non-cross-listed stocks are presented in columns 3 and 4, respectively. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks		**Non-Cross-Listed Stocks**	
March 18	Inflection Trade	Non-Inflection Trade	Inflection Trade	Non-Inflection Trade
Day	-8	56	-37	138
	0.04	0.0	0.0	0.0
Morning	-4	50	-39	36
	0.10	0.0	0.0	0.49
Pre	-2	52	-12	114
	0.40	0.0	0.34	0.0
Post	-8	56	-21	113
	0.13	0.0	0.01	0.0
March 19				
Day	-4	35	-33	27
	0.09	0.0	0.0	0.28
Morning	-3	40	0	-15
	0.67	0.0	0.98	0.68
Pre	-2	32	-32	61
	0.52	0.0	0.02	0.04
Post	-3	37	-57	32
	0.14	0.0	0.0	0.33

Table 3.19: Order Flow CIRFs for 1,000 share *New Bid*

This table reports the average *Inflection* and *Non-Inflection* trade order flow CIRFs for VAR Model 2 from a *New Bid* impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *New Bid* impulse. For example, the *Inflection* trade order flow CIRF of -27 shares (i.e. sell 27 shares) and *Non-Inflection* trade order flow CIRF of 32 shares for the day of March 18th for cross-listed stocks in columns 1 and 2, respectively, are solely the result of their endogenous responses. *Inflection* and *Non-Inflection* trade order flow CIRFs for non-cross-listed stocks are presented in columns 3 and 4, respectively. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks		Non-Cross-Listed Stocks	
March 18	Inflection Trade	Non-Inflection Trade	Inflection Trade	Non-Inflection Trade
Day	-27	32	-39	27
	0.0	0.0	0.01	0.25
Morning	-25	45	-33	-2
	0.0	0.0	0.22	0.96
Pre	-77	30	-35	41
	0.13	0.15	0.05	0.16
Post	-20	22	-20	31
	0.0	0.02	0.05	0.20
March 19				
Day	-24	1	-51	31
	0.0	0.92	0.01	0.44
Morning	-22	1	-10	40
	0.0	0.90	0.64	0.25
Pre	-25	4	-102	-5
	0.0	0.81	0.06	0.89
Post	-42	0	-77	64
	0.0	0.98	0.07	0.37

VAR Model 2 highlights the additional mechanics involved in the price discovery process. *Inflection* trades have equivalent importance to *Non-Inflection* trades in price formation, containing similar information despite generating less follow-on trading activity. Passive order flow produces distinct reactions from the market, but this may be due to information contained by the orders or information about liquidity in the US market. Assuming the passive order flow for cross-listed stocks is in fact uninformed, the VAR model produces a measure of liquidity as opposed to information. Cross-listed stocks have greater price moves but lower information measures, while producing more informed endogenous order flow, than non-cross-listed stocks. Combined with the liquidity driven endogenous passive order flow of the non-cross-listed stocks, the VAR model generates either an inverse measure of information or an indication of the degree of illiquidity for a stock.

Appendix 3.10 reports a robustness check for VAR Model 2, where the *Inflection* trades include the first and the last trade in a sequence. The contrast in results with VAR Model 2 suggest the VAR Model is measuring liquidity instead of information. The revised *Inflection* trade definition increases/decreases the return CIRFs for *Non-Inflection*/*Inflection* trades, implying the last trade in a sequence has below average information content, which is consistent with the contrarian trading strategy literature that postulates the longer a trend persists, the more likely traders informed about liquidity are to trade against the trend (Caginalp et al., 2000). The alternative is

to think that trade information is determined by the trade's place in a sequence and not the information in the mind of the trader entering the order; a trader placing an order that is fourth in a sequence has different information than the same trader placing an order that is in the third or fifth place in the sequence.

3.4.3: VAR Model 3

Early literature took the position that trade size was directly related to the information content of an order, with larger trades containing more information (Easley and O'Hara, 1987). Subsequent research raised the possibility that traders attempt to hide their trading activity, engaging in "stealth" trading, typically by reducing their trade size to make their trades less noticeable (Keim and Madhavan, 1995). To investigate the impact of trade size on information measured by the VAR mode, trades are divided into three categories. *Greater Than* trades are larger than the disclosed volume at the best bid or ask price when the trade is executed. *Equal To* trades are the same size as the disclosed bid and ask volume, with *Less Than* trades being smaller than the disclosed bid and ask volume. The average number and size of the trades in each category is reported in Table 3.20. There are no results from one stock (Fairfax Financial, part of the cross-listed stocks subgroup) on March 18th, due to an insufficient number of trades in each trading category. *Greater Than* trades are more than twice the size of the other trading categories but are less frequent. The impact of the information release in the Post subperiod on March 18 is noticeable in the increase in the number of observations compared to the same subperiod on March 19, with the interesting reversal of the average size of the trade observations (average trade size falls on March 18 but rises on March 19 for the Post subperiod).

Table 3.20: Average Number of Observations and Average Size per Observation

The table below reports the average number of trade observations (Ave # Obs columns) and their average size (Ave Size per Obs columns), respectively, for the *Greater Than* (columns 1 and 2), *Equal To* (columns 3 and 4), and *Less Than* (columns 5 and 6) trade categories used in VAR Model 3. Data for cross-listed and non-cross-listed stocks are presented in separate panels. For example, for the day of March 18th, the average number of *Greater Than* trades for cross-listed stocks is 981 and their average size is 896 shares. Columns 7 and 8 in each panel contain the time weight average number of shares at the best bid and offer for the corresponding subperiods. For example, the time weighted average number of shares at the best bid price for the day of March 18th is 1,592.

Average Number and Size of Trade Observations – Cross-listed Stocks								
	Greater Than		Equal to		Less than		Time Weighted Bid Size	Time Weighted Ask Size
March 18	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs		
Day	981	896	1,806	380	5,858	231	1,592	1,569
Morning	378	876	651	370	1,986	248	1,525	1,381
Pre	153	920	292	459	979	246	1,772	1,749
Post	450	894	864	366	2,894	215	1,458	1,605
March 19								
Day	791	1,049	1,439	415	4,984	238	1,722	1,802
Morning	469	1,067	817	381	2,572	239	1,527	1,595
Pre	158	1,060	321	464	1,127	226	1,718	1,790
Post	164	1,086	301	507	1,285	245	2,005	2,112

Average Number and Size of Trade Observations – Non-Cross-listed Stocks								
	Greater Than		Equal to		Less than		Time Weighted Bid Size	Time Weighted Ask Size
March 18	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs		
Day	236	1,658	433	754	917	307	2,294	2,538
Morning	100	1,643	171	596	341	298	2,205	2,486
Pre	44	1,563	91	969	197	314	2,649	2,636
Post	92	1,679	171	761	379	313	1,966	2,485
March 19								
Day	228	1,669	415	811	870	332	2,583	2,590
Morning	117	1,630	208	797	403	342	2,192	2,166
Pre	54	1,594	99	860	201	300	2,390	2,612
Post	57	2,002	109	894	266	334	3,391	3,166

The return CIRFs for VAR Model 3 (Table 3.21) show a curious pattern in which the *Equal To* trades have a higher return CIRF, and therefore more information, than the *Greater Than* trades. Since the *Greater Than* trades can buy or sell at least as much, relative to the prevailing bid or ask volume, as the *Equal To* trades, it is not clear why the *Greater Than* trades have lower price impact as the direct change in the posted bid or ask is at least as large for *Greater Than* trades. This result contradicts literature positively correlating trade size and information impounding (Easley and O'Hara, 1987) but is consistent with the market interpreting trade size in the context of stealth trading, in which institutions and insiders tend to use medium sized trades (Alexander and Peterson, 2007; Chakravarty, 2001; Keim and Madhavan, 1995). *Less Than* trades produce the lowest return CIRFs, consistent with trade size literature (Barclay and Warner, 1993). Similar to VAR Models 1 and 2, the non-cross-listed stocks produce higher return CIRFs than cross-listed stocks for all trade types. Passive order return CIRFs are close to those in VAR Models 1 and 2

and will not be discussed in this section, which will focus on the active trades (full results are presented in Appendix 3.11).

Differences in the number of trades should be accounted for in the discussion of information content by order size. *Equal To* trades occur twice as often as *Greater Than* trades and have higher return CIRFs, exacerbating the view that *Greater Than* trades impound less information in market prices than *Equal To* trades. *Less Than* trades occur three as often as *Equal To* trades, indicating that *Less Than* trades contribute similar amounts of information to the market as *Equal To* trades; in some subperiods, such as the Post subperiod on March 18, *Less Than* trades may reveal the most information of all order sizes. In a counter-intuitive twist, traders interested in reducing their price impact should use *Greater Than* sized trades, which may be perceived as uninformed because they do not appear to be trying to minimize price impact.

Table 3.21: Return CIRFs for Active Trade Impulses

The table below presents the average bid and ask return CIRFs for *Greater Than, Equal To, and Less Than* trades, broken down by subperiod and subgroup. Column 1, for example, reports an average bid return CIRF of 0.062% for a *Greater Than* trade impulse in the day subperiod of March 18th for cross-listed stocks. The corresponding ask return CIRF is 0.063%. Average return CIRFs for *Equal To* and *Less Than* trade impulses are presented in columns 2 and 3 for cross-listed stocks. Return CIRFs for non-cross-listed stocks are reported in columns 4 through 6. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			**Non-Cross-Listed**		
	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
March 18	Impulse	Impulse	Impulse	Impulse	Impulse	Impulse
Day	0.062%	0.078%	0.035%	0.087%	0.115%	0.056%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.063%	0.087%	0.035%	0.066%	0.120%	0.053%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.077%	0.094%	0.037%	0.100%	0.133%	0.044%
	0.0	0.0	0.0	0.0	0.0	0.02
	0.070%	0.097%	0.026%	0.077%	0.124%	0.038%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.058%	0.066%	0.024%	0.059%	0.069%	0.023%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.066%	0.074%	0.023%	0.053%	0.089%	0.028%
	0.0	0.0	0.0	0.0	0.0	0.0
Post	0.059%	0.083%	0.040%	0.085%	0.116%	0.051%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.061%	0.100%	0.046%	0.069%	0.122%	0.059%
	0.0	0.0	0.0	0.0	0.0	0.0

March 19						
Day	0.048%	0.071%	0.024%	0.073%	0.116%	0.045%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.044%	0.072%	0.031%	0.061%	0.117%	0.046%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.059%	0.097%	0.030%	0.090%	0.139%	0.051%
	0.0	0.0	0.04	0.0	0.0	0.0
	0.058%	0.098%	0.046%	0.078%	0.131%	0.049%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.048%	0.061%	0.024%	0.083%	0.103%	0.028%
	0.0	0.0	0.0	0.0	0.0	0.01
	0.042%	0.068%	0.021%	0.068%	0.122%	0.026%
	0.0	0.0	0.03	0.0	0.0	0.0
Post	0.037%	0.054%	0.020%	0.048%	0.074%	0.016%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.035%	0.059%	0.024%	0.050%	0.076%	0.024%
	0.0	0.0	0.0	0.0	0.0	0.0

Tables 3.22, 3.23, and 3.24 provide insight into the different mechanisms operating with each trade size (see Appendix 3.12 for passive order components of the return CIRFs). Both *Greater Than* and *Equal To* derive most of their return CIRF from their own impulse (i.e. *Greater Than* generates most of the return CIRF for a *Greater Than* impulse), but *Equal To* has more contribution from *New Bid* order flow than *Greater Than* (see Appendix 3.12). Interestingly, the VAR model suggests that the market sees more pricing information in an *Equal To* trade than a *Greater Than* trade. Perhaps an *Equal To* trade is viewed as being intentionally chosen and therefore originating with an institution instead of an individual (Chakravarty, 2001). Although the relatively small size of the *Less Than* trades would seem to lend themselves to stealth trading, the results in Table 3.24 suggest the market is not fooled – more than half of *Less Than* trades' return CIRF is attributable to *Greater Than* and *Equal To* trades spawned by the *Less Than* trade impulse. If *Less Than* trades were stealthy, the market would not take them more seriously than they take *Greater Than* or *Equal To* trades; only *Less Than* trades generate return responses attributable to the other order sizes.

Table 3.22: Bid Return CIRF breakdown for 1,000 share *Greater Than* Trade Impulse

This table reports the *Greater Than*, *Equal To*, and *Less Than* trade components of the average bid return CIRFs for VAR Model 3 from a *Greater Than* trade impulse (the bid return CIRFs from columns 1 and 4 in Table 3.21) over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Greater Than*, *Equal To*, and *Less Than* trades presented in columns 2, 3, and 4, respectively. Differences between column 1 and the sum of columns 2 through 4 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is

0.062%, with *Greater Than* trades contributing 0.075%, *Equal To* trades contributing 0.000%, and *Less Than* trades contributing 0.000% (the difference of -0.013% between 0.062% and total *Greater Than*, *Equal To*, and *Less Than* trade contribution of 0.075% is attributable to the omitted variables). The *Greater Than* trade contribution includes the exogenous *Greater Than* trade impulse, but the *Equal To* and *Less Than* trade contributions are solely due to their endogenous responses. Analogous results for non-cross-listed stocks are reported in columns 5 through 8. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks				Non-Cross-Listed Stocks			
March 18	CIRF	by Greater Than	by Equal To	by Less Than	CIRF	by Greater Than	by Equal To	by Less Than
Day	0.062%	0.075%	0.000%	0.000%	0.087%	0.104%	0.001%	-0.001%
	0.0	0.0	0.17	0.04	0.0	0.0	0.22	0.13
Morning	0.077%	0.096%	-0.001%	-0.001%	0.100%	0.122%	0.001%	-0.001%
	0.0	0.0	0.08	0.09	0.0	0.0	0.58	0.22
Pre	0.058%	0.060%	0.000%	0.000%	0.059%	0.063%	0.000%	0.000%
	0.0	0.0	0.59	0.92	0.0	0.0	0.97	0.24
Post	0.059%	0.065%	0.000%	0.000%	0.085%	0.105%	0.001%	-0.001%
	0.0	0.0	0.73	0.06	0.0	0.0	0.30	0.14
March 19								
Day	0.048%	0.054%	0.000%	0.000%	0.073%	0.087%	0.002%	0.000%
	0.0	0.0	0.42	0.33	0.0	0.0	0.33	0.41
Morning	0.059%	0.071%	0.000%	-0.001%	0.090%	0.108%	0.002%	0.000%
	0.0	0.0	0.87	0.12	0.0	0.0	0.64	0.57
Pre	0.048%	0.052%	0.002%	0.000%	0.083%	0.092%	-0.002%	0.000%
	0.0	0.0	0.09	0.12	0.0	0.0	0.27	0.20
Post	0.037%	0.039%	0.000%	0.000%	0.048%	0.054%	0.000%	0.000%
	0.0	0.0	0.51	0.46	0.0	0.0	0.89	0.97

Table 3.23: Bid Return CIRF breakdown for 1,000 share *Equal To* Trade Impulse

This table reports the *Greater Than*, *Equal To*, and *Less Than* trade components of the average bid return CIRFs for VAR Model 3 from an *Equal To* trade impulse (the bid return CIRFs from columns 2 and 5 in Table 3.21) over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Greater Than*, *Equal To*, and *Less Than* trades presented in columns 2, 3, and 4, respectively. Differences between column 1 and the sum of columns 2 through 4 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.078%, with *Greater Than* trades contributing 0.002%, *Equal To* trades contributing 0.080%, and *Less Than* trades contributing 0.000% (the difference of -0.004% between 0.078% and total *Greater Than*, *Equal To*, and *Less Than* trade contribution of 0.082% is attributable to the omitted variables). The *Equal To* trade contribution includes the exogenous *Equal To* trade impulse, but the *Greater Than* and *Less Than* trade contributions are solely due to their endogenous responses. Analogous results for non-cross-listed stocks are reported in columns 5 through 8. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks				Non-Cross-Listed Stocks			
March 18	CIRF	by Greater Than	by Equal To	by Less Than	CIRF	by Greater Than	by Equal To	by Less Than
Day	0.078%	0.002%	0.080%	0.000%	0.115%	0.009%	0.105%	0.001%
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.25
Morning	0.094%	0.004%	0.099%	0.000%	0.133%	0.007%	0.130%	0.000%
	0.0	0.05	0.0	0.02	0.0	0.0	0.0	0.71
Pre	0.066%	0.001%	0.064%	0.000%	0.069%	0.001%	0.067%	0.000%
	0.0	0.31	0.0	0.03	0.0	0.68	0.0	0.83
Post	0.083%	0.002%	0.075%	0.000%	0.116%	0.007%	0.112%	0.000%
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.45
March 19								
Day	0.071%	0.002%	0.073%	0.000%	0.116%	0.006%	0.129%	0.000%
	0.0	0.0	0.0	0.28	0.0	0.01	0.0	0.33
Morning	0.097%	0.001%	0.107%	0.000%	0.139%	0.003%	0.157%	0.000%
	0.0	0.32	0.0	0.92	0.0	0.47	0.0	0.62
Pre	0.061%	0.001%	0.058%	0.000%	0.103%	0.000%	0.106%	0.000%
	0.0	0.29	0.0	0.04	0.0	0.95	0.0	0.56
Post	0.054%	0.001%	0.052%	0.000%	0.074%	0.006%	0.080%	0.000%
	0.0	0.01	0.0	0.11	0.0	0.01	0.0	0.34

Table 3.24: Bid Return CIRF breakdown for 1,000 share *Less Than* Trade Impulse

This table reports the *Greater Than*, *Equal To*, and *Less Than* trade components of the average bid return CIRFs for VAR Model 3 from a *Less Than* trade impulse (the bid return CIRFs from columns 3 and 6 in Table 3.21) over a 100-tick period following the impulse. For cross-listed stocks, the average bid return CIRFs are in column 1, with the contribution of *Greater Than*, *Equal To*, and *Less Than* trades presented in columns 2, 3, and 4, respectively. Differences between column 1 and the sum of columns 2 through 4 are attributable to the variables omitted from presentation in this table (*Change to Existing Bid*, *New Bid*, *Bid Price Change*, *Change to Existing Ask*, *New Ask*, and *Ask Price Change*). For example, for the day of March 18th, the average bid return CIRF for cross-listed stocks is 0.035%, with *Greater Than* trades contributing 0.007%, *Equal To* trades contributing 0.009%, and *Less Than* trades contributing 0.016% (the difference of 0.003% between 0.035% and total *Greater Than*, *Equal To*, and *Less Than* trade contribution of 0.032% is attributable to the omitted variables). The *Less Than* trade contribution includes the exogenous *Less Than* trade impulse, but the *Greater Than* and *Equal To* trade contributions are solely due to their endogenous responses. Analogous results for non-cross-listed stocks are reported in columns 5 through 8. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed Stocks				Non-Cross-Listed Stocks			
March 18	CIRF	by Greater Than	by Equal To	by Less Than	CIRF	by Greater Than	by Equal To	by Less Than
Day	0.035%	0.007%	0.009%	0.016%	0.056%	0.017%	0.017%	0.009%
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.26
Morning	0.037%	0.007%	0.009%	0.019%	0.044%	0.016%	0.015%	0.000%
	0.0	0.0	0.0	0.0	0.02	0.01	0.0	0.98
Pre	0.024%	0.004%	0.004%	0.007%	0.023%	0.011%	0.005%	-0.003%
	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.46
Post	0.040%	0.007%	0.010%	0.015%	0.051%	0.014%	0.016%	0.003%
	0.0	0.0	0.0	0.0	0.0	0.09	0.0	0.76
March 19								
Day	0.024%	0.006%	0.007%	0.005%	0.045%	0.012%	0.019%	0.014%
	0.0	0.0	0.0	0.51	0.0	0.0	0.0	0.08
Morning	0.030%	0.009%	0.018%	-0.001%	0.051%	0.011%	0.026%	0.013%
	0.04	0.0	0.02	0.93	0.0	0.0	0.0	0.16

Pre	0.024%	0.000%	0.004%	0.012%	0.028%	0.006%	0.005%	0.011%
	0.0	0.85	0.0	0.0	0.01	0.41	0.03	0.15
Post	0.020%	0.004%	0.004%	0.006%	0.016%	0.004%	0.003%	0.004%
	0.0	0.0	0.0	0.0	0.0	0.10	0.53	0.56

Tables 3.25, 3.26, and 3.27 Table 3.Table 3.contain the order flow CIRFs for the trade impulses commensurate with the return CIRFs in the preceding tables (Appendix 3.13 contains complete order flow results). The *Greater Than* trade impulses generate a muted response from the other active trade types, with some of the active order flow being in the opposite direction of the *Greater Than* impulse. The order flow results support the return CIRFs and imply the market does not view *Greater Than* trades as containing information; *Greater Than* trades spawn neither return nor order follow-on activity. *Equal To* trades create larger order flow CIRFs than *Greater Than* trades, which is consistent with the return CIRFs and literature on stealth trading (Alexander and Peterson, 2007; Barclay and Warner, 1993). The market reacts to *Equal To* trades as though they are informed, with subsequent trading interest.

Less Than trades offer a conundrum. *Less Than* trades have the largest order flow CIRFs, with active trade responses increasing the total active trading volume by 50%+ over the initial *Less Than* trade impulse, including more endogenous *Greater Than* trades than *Equal To* trades; *Less Than* trades spawn trades in the other categories, but the vice versa is not true, even though *Less Than* trades produce the lowest return CIRFs on a share-for-share basis. Except for some increases in the existing ask size, the order flow CIRFs reveal the market is reacting to the *Less Than* orders as though they are informed (see Appendix 3.13). *Less Than* trades manage to produce the lowest return CIRFs while having the largest active and passive order. Perhaps the *Less Than* trades are successful at masking information, or in the very least minimizing price impact, at least on per impulse basis. *Less Than* trades are the most numerous order size in the market, accounting for approximately 57% to 67% of all orders, for non-cross-listed and cross-listed stocks, respectively, but only between 28% and 46% of traded volume. If the VAR model is correct, *Less Than* trades would account for almost 70% of the volume for cross-listed stocks and nearly 50% of the volume for non-cross-listed stocks (assuming all *Less Than* trading volume constitute trade impulses). Evaluating information content on a per order basis may be a mistake,

given the size of the *Less Than* trading footprint in the market. The VAR model may also overestimate the influence of *Greater Than* and *Equal To* trades since half of their volume traded is attributable to a *Less Than* trade; does the VAR model estimate the information content from the portion of *Greater Than* or *Equal To* trades that exogenously generated?

Table 3.25: Order Flow CIRFs for 1,000 share *Greater Than* Trade

This table reports the average *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for VAR Model 3 from a *Greater Than* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Greater Than* trade impulse. For example, the *Greater Than* trade order flow CIRF of 27 shares for the day of March 18th for cross-listed stocks in column 1 does not include the initial 1,000 share *Greater Than* trade impulse and represents only the follow-on *Greater Than* trade activity. The *Equal To* and *Less Than* trade CIRFs in columns 2, 3, 5, and 6 are solely the result of their endogenous responses. For example, the *Greater Than* trade impulse induces an average *Equal To* trade response of 0 shares for the day subperiod on March 18th in column 2 for cross-listed shares, entirely endogenously. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			**Non-Cross-Listed**		
March 18	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
Day	27	0	-17	66	12	2
	0.0	0.97	0.0	0.0	0.06	0.71
Morning	35	-3	-14	53	5	-4
	0.0	0.52	0.11	0.0	0.51	0.50
Pre	18	-6	-25	35	1	-1
	0.0	0.07	0.01	0.02	0.91	0.90
Post	21	3	-16	56	4	2
	0.0	0.33	0.02	0.0	0.45	0.82
March 19						
Day	33	3	-15	99	7	7
	0.0	0.21	0.06	0.0	0.45	0.52
Morning	32	1	-15	89	25	6
	0.0	0.86	0.07	0.01	0.13	0.61
Pre	20	13	-26	51	-11	-1
	0.05	0.0	0.07	0.03	0.29	0.86
Post	37	-3	5	43	-9	6
	0.0	0.55	0.52	0.02	0.30	0.71

Table 3.26: Order Flow CIRFs for 1,000 share *Equal To* Trade

This table reports the average *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for VAR Model 3 from an *Equal To* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Equal To* trade impulse. For example, the *Equal To* trade order flow CIRF of 56 shares for the day of March 18th for cross-listed stocks in column 2 does not include the initial 1,000 share *Equal To* trade impulse and represents only the follow-on *Equal To* trade activity. The *Greater Than* and *Less Than* trade CIRFs in columns 1, 3, 4, and 6 are solely the result of their endogenous responses. For example, the *Equal To* trade impulse induces an average *Greater Than* trade response of 42 shares for the day subperiod on March 18th in column 1 for cross-listed shares, entirely endogenously. For each average, a standard T-Statistic is calculated with the null hypothesis that the

average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			Non-Cross-Listed		
March 18	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
Day	42	56	52	106	89	78
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	53	50	50	57	63	55
	0.0	0.0	0.0	0.04	0.0	0.0
Pre	14	30	40	77	56	70
	0.06	0.0	0.0	0.30	0.0	0.0
Post	37	51	44	120	52	43
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	51	53	66	104	107	67
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	50	62	77	128	87	65
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	35	34	32	4	56	23
	0.0	0.0	0.0	0.91	0.01	0.03
Post	45	36	54	95	63	33
	0.0	0.0	0.0	0.03	0.0	0.07

Table 3.27: Order Flow CIRFs for 1,000 share *Less Than* Trade

This table reports the average *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for VAR Model 3 from a *Less Than* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Less Than* trade impulse. For example, the *Less Than* trade order flow CIRF of 479 shares for the day of March 18th for cross-listed stocks in column 3 does not include the initial 1,000 share *Less Than* trade impulse and represents only the follow-on *Less Than* trade activity. The *Greater Than* and *Equal To* trade CIRFs in columns 1, 2, 4, and 5 are solely the result of their endogenous responses. For example, the *Less Than* trade impulse induces an average *Greater Than* trade response of 127 shares for the day subperiod on March 18th in column 1 for cross-listed shares, entirely endogenously. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			Non-Cross-Listed		
March 18	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
Day	127	109	479	201	155	337
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	131	106	438	139	143	292
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	93	72	353	421	103	244
	0.0	0.0	0.0	0.06	0.0	0.0
Post	140	117	531	166	116	301
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	134	97	452	194	139	259
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	129	110	439	192	174	274
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	92	87	400	131	74	107
	0.0	0.0	0.0	0.01	0.0	0.0
Post	131	77	410	90	58	204
	0.0	0.0	0.0	0.03	0.02	0.0

The reaction of endogenous *Greater Than*, *Equal To*, and *Less Than* trades to passive order flow is shown in Tables 3.28 and 3.29 (full results in Appendix 3.14). The results are similar to those from VAR Model 1 (Tables 3.7 and 3.8) and VAR Model 2 (Tables 3.18 and 3.19) with muted trade responses from passive order flow, and generally contrarian trade flows in response to *New Bids*. There is a larger *Greater Than* response, most notably with respect to *New Bids*, which may help explain the lower return CIRFs for *Greater Than* trades given their apparent liquidity seeking nature.

Table 3.28: Order Flow CIRFs for 1,000 share *Change to Existing Bid*

This table reports the average *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for VAR Model 3 from a *Change to Existing Bid* impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Change to Existing Bid* impulse. For example, the *Greater Than* trade order flow CIRF of 16 shares, *Equal To* trade order flow CIRF of 17 shares, *Less Than* trade order flow CIRF of 15 shares for the day of March 18th for cross-listed stocks in columns 1, 2, and 3, respectively, are solely the result of their endogenous responses. *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for non-cross-listed stocks are presented in columns 4, 5, and 6, respectively. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			**Non-Cross-Listed**		
March 18	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
Day	16	17	15	4	40	43
	0.0	0.0	0.0	0.84	0.0	0.0
Morning	18	15	9	-51	12	31
	0.0	0.0	0.01	0.07	0.40	0.05
Pre	17	17	10	80	36	42
	0.0	0.0	0.12	0.06	0.0	0.03
Post	13	15	20	19	25	36
	0.05	0.0	0.0	0.14	0.04	0.03
March 19						
Day	17	9	2	12	-9	5
	0.0	0.0	0.68	0.51	0.68	0.60
Morning	18	13	-4	16	7	-37
	0.0	0.0	0.46	0.22	0.74	0.02
Pre	14	7	9	7	2	26
	0.0	0.01	0.04	0.79	0.87	0.20
Post	13	6	12	-6	-4	-6
	0.0	0.0	0.0	0.74	0.79	0.70

Table 3.29: Order Flow CIRFs for 1,000 share *New Bid*

This table reports the average *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for VAR Model 3 from a *New Bid* impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *New Bid* impulse. For example, the *Greater Than* trade order flow CIRF of -8 shares (i.e. sell 8 shares), *Equal To* trade order flow CIRF of 1 share, *Less Than* trade order flow CIRF of 5 shares for the day of March 18th for cross-listed stocks in columns 1, 2, and 3, respectively, are solely the result of their endogenous responses. *Greater Than*, *Equal To*, and *Less Than* trade order flow CIRFs for non-cross-listed stocks are presented in columns 4, 5, and 6, respectively. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Cross-Listed			**Non-Cross-Listed**		
March 18	Greater Than	Equal To	Less Than	Greater Than	Equal To	Less Than
Day	-8	1	5	-38	9	21
	0.15	0.89	0.38	0.01	0.42	0.15
Morning	7	1	6	-43	0	20
	0.30	0.91	0.42	0.04	1.0	0.14
Pre	-51	-2	5	32	8	0
	0.27	0.80	0.63	0.23	0.71	1.0
Post	-12	1	9	-50	-5	33
	0.01	0.80	0.12	0.01	0.82	0.05
March 19						
Day	-2	-13	-13	8	-27	-10
	0.80	0.0	0.0	0.82	0.19	0.42
Morning	1	-8	-21	26	-9	-2
	0.87	0.07	0.0	0.45	0.25	0.87
Pre	-9	-24	-5	-101	3	-12
	0.31	0.02	0.59	0.21	0.88	0.37
Post	-25	-25	-8	9	-17	-8
	0.0	0.01	0.40	0.75	0.63	0.74

In order for the *Greater Than* trades to be viewed as being uninformed because they appear naïve in the sense that they do not appear to be adjusting for the size of the liquidity available at the best bid or ask, the trade signal that the buyer or seller is aggressively pushing the available liquidity must be discounted by the market. The same rationale may apply to the *Less Than* trades as they are similarly easy to execute at less than the size of the volume at the best bid or ask price without any thought or intention. Conversely, the *Equal To* trades, roughly conforming to the medium sized trades in the literature, look to be intentionally sized to take exactly the liquidity that is available at the top of the book. Despite the range of order sizes, passive and active, *Equal To* trades average 19% to 34% of the active order flow across both stock subgroups, which is larger than would be expected if the active and passive orders were randomly matched (see Appendix 3.15). The non-random nature of the order size selection is reinforced by the average

trade volumes for all order types being less than the time weighted average bid and ask sizes (last two columns of Table 3.20); all trades could be executed as *Less Than* trades, but are not.

The *Equal To* trades could be interpreted as taking as much liquidity as possible without creating a price tick outside the BBO, which fits into the idea of stealthy trading (maximizing traded volume while minimizing price impact). In contrast, *Greater Than* trades do not appear to be hiding any of their trade signal, and *Less Than* trades leave liquidity on the table. The market could be assigning its informational interpretation, and subsequent return CIRFs, accordingly; the market has a nuanced approach to reading intent from trading activity.

The order flow reaction, however, says something different. *Less Than* trades spawn multiple times the follow-on trading volume as *Greater Than* and *Equal To* trades. If the market viewed the *Less Than* trades as less informed, why would so much trading volume, including *Greater Than* and *Equal To* trades, respond to the *Less Than* trade impulse? One possibility is that the VAR model is incorrectly measuring the price or order flow impact. The passive order flow may be part of the answer. If *Less Than* trades produce more trading activity but less price movement, there may be more passive order flow resistance than for *Equal To* trades. The data in the model uses the changes in the variables but does not incorporate their starting points (e.g. an existing bid change of 500 could increase the prevailing bid size from 1,000 to 1,500 or 5,000 to 5,500) and the non-random nature of the order size selection could be intentionally timing orders to achieve a specific market reaction.

3.4.4: VAR Model 4

VAR Models 2 and 3 suggest that patterns in the active trading data influence the return and order flow CIRFs. VAR Model 4 combines the trade separations from VAR Models 2 and 3, segmenting active trades by both *Inflection* vs. *Non-Inflection* and *Greater Than*, *Equal To*, and *Less Than* trade sizes, creating six individual active trade categories. For stocks with fewer trade observations, the additional trade categories create problems with coefficient calculations. There

are no results from one stock (Fairfax Financial, part of the cross-listed subgroup) on March 18th, and for another stock (Bombardier, part of the non-cross-listed subgroup) in the afternoon subperiods on March 19th. Similar to the previous sections, the focus of the results will be on the active trading categories as the passive order results are similar to those reported earlier.

Table 3.30 shows the average order number and size for each active trade category. The additional granularity illustrates a pattern in the trade data that is not apparent in the other models. In this case, the *Inflection Greater Than* trades in the cross-listed subgroup are smaller than the *Non-Inflection Greater Than* trades, although *Inflection* trades are larger than *Non-Inflection* trades in the other categories and in VAR Model 2. This may be pointing to something different happening with *Greater Than* trades that is reflected in the lower return CIRFs compared to the *Equal To* trades. The average trade size for the *Inflection Equal To* trades in the Pre subperiod on March 18th for non-cross-listed stocks highlights the difficulty of working with progressively smaller subsets of data, as the average trade is outsized compared to other subperiods, possibly due to the presence of a large outlier in a small set of data (i.e. only 30 observations on average for this category and time period). Data subsets that could not produce a result (e.g. AIC = 0) are excluded from the summary statistics. Another interesting observation is the higher proportion of *Non-Inflection* trades for the *Less Than* category, as a proportion of all *Less Than* trades (i.e. *Non-Inflection* trades are more likely for *Less Than* compared to *Greater Than* and *Equal To*). The large proportion of *Non-Inflection Less Than* trades may explain why *Non-Inflection* trades from VAR Model 2 have similar return CIRFs for *Less Than* trades from VAR Model 3, given the lower return CIRFs for *Less Than* trades. There are demographic cross-effects in the trading data that may cause a misallocation of origin for the VAR Model results; *Non-Inflection* trades may have lower CIRFs because they are *Non-Inflection* trades and not because they are *Less Than* trades.

Table 3.30: Average Number of Observations and Average Size per Observation

The table below reports the average number of trade observations (Ave # Obs columns) and their average size (Ave Size per Obs columns), respectively, for the *Inflection Greater Than* (columns 1 and 2), *Inflection Equal To* (columns 3 and 4), *Inflection Less Than* (columns 5 and 6), *Non-Inflection Greater Than* (columns 7 and 8), *Non-Inflection Equal To* (columns 9 and 10), and *Non-Inflection Less Than* (columns 11 and 12) trade categories used in VAR Model 4. Data

for cross-listed and non-cross-listed stocks are presented in separate panels. For example, for the day of March 18th, the average number of *Inflection Greater Than* trades for cross-listed stocks is 645 and their average size is 700 shares.

Average Number and Size of Trade Observations – Cross-listed Stocks

	Inflection Greater Than		Inflection Equal To		Inflection Less Than		Non-Inflection Greater Than		Non-Inflection Equal To		Non-Inflection Less Than	
March 18	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs
Day	645	700	563	491	1,514	266	812	775	1,244	343	4,344	219
Morning	243	677	203	478	544	277	314	761	448	335	1,442	237
Pre	107	717	91	673	278	275	132	783	201	385	700	235
Post	295	709	269	460	691	252	367	779	595	334	2,202	203
March 19												
Day	486	862	434	558	1,289	276	652	893	1,005	361	3,695	224
Morning	288	877	250	501	668	275	379	894	567	336	1,904	226
Pre	99	889	97	708	296	261	132	898	224	381	831	214
Post	99	861	87	653	325	288	141	941	214	449	960	229

Average Number and Size of Trade Observations – Non-Cross-Listed Stocks

	Inflection Greater Than		Inflection Equal To		Inflection Less Than		Non-Inflection Greater Than		Non-Inflection Equal To		Non-Inflection Less Than	
March 18	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs	Ave # Obs	Ave Size per Obs
Day	154	1,491	144	909	284	325	192	1,355	288	718	633	301
Morning	66	1,511	57	661	107	320	81	1,342	114	570	234	291
Pre	28	1,148	30	2,060	61	320	36	1,304	61	883	136	313
Post	60	1,506	57	861	116	329	75	1,365	114	738	263	307
March 19												
Day	151	1,591	138	1,078	297	339	183	1,385	277	766	574	329
Morning	76	1,455	68	1,044	129	350	94	1,408	140	740	274	340
Pre	39	880	36	669	73	272	44	897	66	434	120	247
Post	38	1,198	36	832	91	276	47	1,090	75	547	167	271

The return CIRFs for the passive impulses correspond to the results observed in VAR Model 2 and VAR Model 3 and are therefore not presented here (see Appendix 3.16 for passive order return CIRFs). For the most part, the return CIRFs for *Inflection Greater Than* and *Inflection Equal To* trades (Table 3.31) are bigger than their corresponding *Non-Inflection* trades, and *Equal To* trades have the highest return CIRFs for both *Inflection* and *Non-Inflection* categories, as seen in the VAR Model 2 and VAR Model 3. The results for *Less Than* trades deviate from VAR Models 2 and 3 with *Non-Inflection Less Than* trades generating higher bid return CIRFs than *Inflection Less Than* trades. *Non-Inflection Less Than* trades also have higher bid returns than *Non-Inflection Greater Than* trades in a quarter of the subperiods. The VAR Model 2 balance between *Inflection* and *Non-Inflection* trade return CIRFs is created by the *Less Than* trades averaging down the *Inflection* CIRFs by a greater amount than the *Non-Inflection* trades. The VAR models are responding to more characteristics in the trading data than is readily apparent from the trade data

categorization used in the model. In some sense, no particular branch of literature is completely correct, or completely incorrect, in describing the price discovery process because they are all right (or wrong) depending on the data used in the VAR model. Results that use a singular measure for active trading, such as Hasbrouck (1991) are bound to produce difficult to interpret results that are open to empirical criticism. Patterns within the market data matter when investigating information impounding.

Table 3.31: Return CIRFs for Active Trade Impulses

The table below presents the average bid and ask return CIRFs for *Inflection Greater Than, Inflection Equal To, Inflection Less Than*, *Non-Inflection Greater Than, Non-Inflection Equal To*, and *Non-Inflection Less Than* trades, broken down by subperiod and subgroup. Column 1, for example, reports an average bid return CIRF of 0.055% for an *Inflection Greater Than* trade impulse in the day subperiod of March 18th for cross-listed stocks. The corresponding ask return CIRF is 0.050%. Average return CIRFs for *Inflection Equal To* and *Inflection Less Than* trade impulses are presented in columns 2 and 3, with columns 4 through 6 reporting the *Non-Inflection Greater Than, Non-Inflection Equal To*, and *Non-Inflection Less Than* return CIRFs. Cross-listed and non-cross-listed results are reported in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

			Cross-Listed Stocks			
March 18	Inflection Greater Than Impulse	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection Greater Than Impulse	Non-Inflection Equal To Impulse	Non-Inflection Less Than Impulse
Day	0.055%	0.081%	0.030%	0.046%	0.077%	0.040%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.050%	0.088%	0.030%	0.050%	0.088%	0.040%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.061%	0.112%	0.029%	0.068%	0.091%	0.039%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.043%	0.095%	0.017%	0.070%	0.108%	0.033%
	0.0	0.0	0.01	0.0	0.0	0.0
Pre	0.033%	0.074%	0.015%	0.068%	0.064%	0.030%
	0.0	0.0	0.0	0.01	0.0	0.0
	0.052%	0.080%	0.018%	0.054%	0.076%	0.027%
	0.0	0.0	0.0	0.0	0.0	0.0
Post	0.050%	0.089%	0.036%	0.042%	0.081%	0.043%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.042%	0.097%	0.040%	0.051%	0.099%	0.053%
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	0.049%	0.072%	0.008%	0.035%	0.074%	0.033%
	0.0	0.0	0.64	0.0	0.0	0.0
	0.041%	0.078%	0.026%	0.033%	0.074%	0.036%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.059%	0.100%	0.008%	0.045%	0.101%	0.043%
	0.0	0.0	0.78	0.0	0.0	0.0
	0.057%	0.117%	0.031%	0.040%	0.099%	0.054%
	0.0	0.0	0.01	0.0	0.0	0.0

Pre	0.036%	0.077%	0.015%	0.041%	0.057%	0.027%
	0.0	0.0	0.08	0.0	0.0	0.0
	0.031%	0.080%	0.002%	0.036%	0.066%	0.026%
	0.0	0.0	0.94	0.0	0.0	0.01
Post	0.038%	0.060%	0.018%	0.031%	0.058%	0.022%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.036%	0.070%	0.019%	0.027%	0.068%	0.021%
	0.0	0.0	0.0	0.0	0.0	0.0

				Non-Cross-Listed Stocks		
March 18	Inflection Greater Than Impulse	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection Greater Than Impulse	Non-Inflection Equal To Impulse	Non-Inflection Less Than Impulse
Day	0.081%	0.133%	0.061%	0.057%	0.108%	0.045%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.056%	0.115%	0.058%	0.051%	0.125%	0.049%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.087%	0.176%	0.063%	0.078%	0.121%	0.038%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.076%	0.132%	0.021%	0.056%	0.120%	0.044%
	0.0	0.0	0.46	0.0	0.0	0.0
Pre	0.067%	0.085%	0.018%	0.022%	0.068%	0.015%
	0.0	0.0	0.05	0.26	0.0	0.0
	0.019%	0.093%	0.030%	0.057%	0.085%	0.022%
	0.13	0.0	0.0	0.0	0.0	0.0
Post	0.061%	0.133%	0.054%	0.075%	0.104%	0.046%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.045%	0.107%	0.067%	0.058%	0.132%	0.056%
	0.0	0.0	0.0	0.0	0.0	0.0
March 19						
Day	0.056%	0.109%	0.038%	0.070%	0.117%	0.047%
	0.0	0.0	0.0	0.0	0.0	0.0
	0.046%	0.128%	0.037%	0.055%	0.116%	0.049%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.075%	0.134%	0.046%	0.077%	0.150%	0.070%
	0.0	0.0	0.0	0.0	0.0	0.01
	0.061%	0.154%	0.046%	0.071%	0.128%	0.070%
	0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.059%	0.116%	0.039%	0.101%	0.117%	-0.005%
	0.0	0.0	0.02	0.0	0.0	0.83
	0.059%	0.156%	0.027%	0.075%	0.145%	0.018%
	0.0	0.0	0.0	0.0	0.0	0.15
Post	0.041%	0.092%	0.013%	0.055%	0.072%	0.019%
	0.0	0.0	0.02	0.0	0.0	0.0
	0.027%	0.087%	0.025%	0.052%	0.081%	0.024%
	0.0	0.0	0.0	0.0	0.0	0.01

The return CIRF component breakdown is consistent with a combination of the results from VAR Models 2 and 3 (see Appendix 3.17 for full results). When *Inflection* and *Non-Inflection* trades are separated for *Greater Than* and *Equal To* trades, an endogenous impact from other size categories is identified, acting through *Non-Inflection* categories. This knock-on effect is not

identified in VAR Model 3 as the *Inflection* trades are cancelling out the *Non-Inflection* trade impact. Similarly, *Less Than* trades in the VAR Model 3 draw half of their bid return CIRFs indirectly from *Greater Than* and *Equal To* trades, which are identified as being in the *Non-Inflection* categories in VAR Model 4. Conversely, the *Non-Inflection* contribution to the *Inflection* bid return CIRFs in VAR Model 2 are driven by *Less Than* trades in VAR Model 4. The component level analysis shows the same impact of pattern inclusion in one model but not another; the results in VAR Models 2 are ignoring the effects in VAR Model 3, and vice versa. The additional trading categories appear to split the trade response to passive order flow across enough categories that no individual category is material, although *Non-Inflection Greater Than* and *Non-Inflection Equal To* trades have the most consistently non-zero responses, and are not presented here (see Appendix 3.18 for the bid return CIRF breakdown for passive order impulses).

The order flow CIRFs for active trade impulses (see Appendix 3.19) show similar patterns to VAR Models 2 and 3. Active trade impulses create *Inflection* trade flow that is in the opposite direction to the impulse and *Non-Inflection* trade flow that is in the same direction, across the size categories. With respect to size, the smaller the trade size category, the more follow-on trading flow, across both *Inflection* and *Non-Inflection* categories. Of interest is the overall increase in gross trading volumes in VAR Model 4 compared to VAR Models 2 and 3. As concluded for the earlier VAR Models, more segmentation of the trading series leads to less netting out of the trading activity forecast by the VAR model and more total volume transacted in the price discovery process. The VAR Model 4 order flow CIRFs for *Less Than* trades produce a 100% response (i.e. 1,000 shares of endogenous trading for a 1,000 share impulse), with 50% and 10% responses for *Equal To* and *Greater Than* impulses, respectively.

Order flow CIRFs for passive order impulses are reported in Appendix 3.20. Similar to VAR Model 2, most of the endogenous trading is *Non-Inflection* for *Change to Existing Bid* but *Inflection* for *New Bid*. Interestingly, the biggest aggregate reaction in both cases is from *Greater Than* trades, reinforcing the earlier note that *Greater Than* trades increasingly appear to be reactionary, which may be factored in by the market when judging the information content of a *Greater Than* trade.

Spreading the responses over more variables reduces their individual materiality, and most of the active trade CIRFs are marginal. Combining the trade segmentations from VAR Models 2 and 3 highlight the importance of trade patterns in the data on the VAR Model results. Even using only two different dimensions to measure trades, a number of nuanced insights have been gained that have not been reported in prior literature. Although this pattern impact has been identified for active trading data, it may also be the same for the passive order variables, which could lead to other patterns or packages of trades as independent variables instead of single observations.

3.5: Alternative Grouping

Differences in results for cross-listed and non-cross-listed subgroups are consistent across all of the models presented in section 3.4. These two groups are separated by a single, easily identifiable characteristic, their listing or not on a non-Canadian exchange. There are other characteristics that are being ignored, in particular the volume (liquidity) of trading in each stock. Some of the cross-listed stocks, for example, do not trade as actively as some non-cross-listed stocks. In this section, select results will be presented with an alternate set of subgroups that are determined by trading volumes.

Figure 3.1 illustrates the four groups. Each range of trades has a distinct range of possible return CIRFs (return CIRFs are from VAR Model 2 and include separate data point for March 18th and March 19th for each stock). The first group is defined as stocks that have more than 15,000 trades per day, the second group has daily trading activity between 5,000 and 15,000 trades per day, the third group has 2,600 to 5,000 trades per day, and the fourth group has fewer than 2,600 trades per day. In no case are there stocks that have daily trades that put them in two different groups.

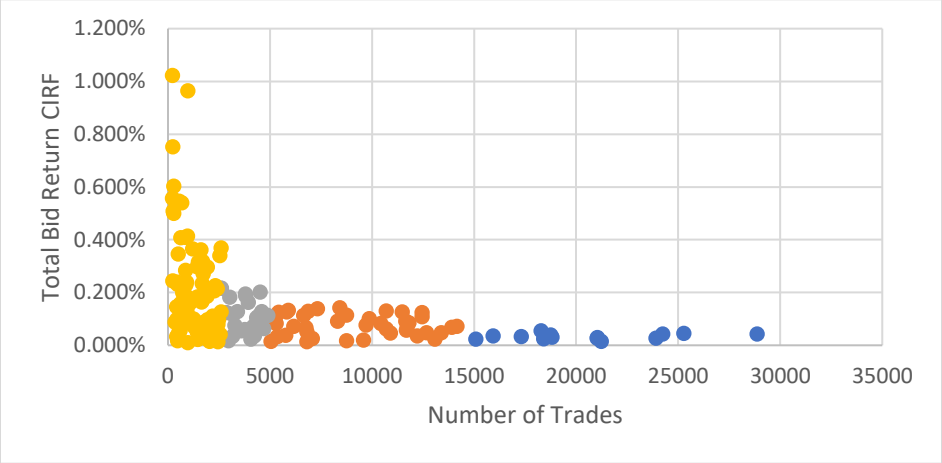
The pattern in Figure 3.1 neatly summarizes the results that will be discussed in this section: return CIRFs are more driven by the level of trading activity (amount of liquidity) than anything else. The most liquid subgroup has the lowest average return CIRF, with average CIRFs rising as

liquidity falls. The price impact of a trade is affected by liquidity, and Figure 3.1 makes it clear that this relationship has a meaningful impact on the return CIRFs across the entire spectrum of trading activity. If we measure information by price impact, how much of the measured price impact is due to information instead of liquidity (or lack thereof)? Further, if price impact is determined by liquidity, does the price move really suggest information about the fundamental value of an asset instead of information about that asset's order flow and would the information about liquidity be held by the active trader or by the passive trader buying or selling at better prices? A liquidity perspective on the VAR measures aligns with the contrarian trading literature, which should show up in the *Inflection* trade return CIRFs.

Group 1 contains the eight largest capitalization stocks listed on the TSX, all of which are cross-listed and are the dominant companies in their respective industries. The companies in Group 1 represent the largest sectors of the Canadian market, Banking and Gold (as of March 2009). Group 2 is formed by the also-ran large capitalization companies in the Banking and Gold sectors along with the leading companies in other sectors, notably Telecom, Tech, Transportation, and Basic Materials. Group 3 are the smallest large-capitalization stocks in the sectors represented in Groups 1 and 2. Group 4 holds companies that are mid-capitalization players in their sectors and represent a diverse group of more narrowly focused niche companies than the other three groups. By way of analogy, the largest national banking firm would be in Group 1, the median sized national bank would be in Group 2. A regional bank would be included in Group 3, and Group 4 would have a niche online lender who only lends money for condo purchases in Toronto.

Figure 3.1: Bid Return CIRFs vs. Number of Trades

The figure below plots the bid return CIRFs (vertical axis) against the number of trades (horizontal axis) for each stock in the dataset. The bid return CIRFs are from VAR Model 2 and there are two data points for each stock, consisting of the day subperiod bid return CIRFs for each of March 18th and March 19th.



The average bid return CIRFs for the alternate subgroups for VAR Model 1 are shown in Table 3.32, which can be read in contrast with the original VAR Model 1 cross-listed and non-cross-listed subgroup return CIRFs in Table 3.2. Not only does the return CIRF rise in each successive group, but the variation in the return CIRF across subperiods also increases. There is little variation in the return CIRF for Group 1 over the course of the day, even on March 18th when there were distinct information processing periods in the Morning and Post subperiods. The lack of variation in Group 1 is particularly notable when compared with the average midpoint change in the post subperiod on March 18th. It appears that at a certain level of liquidity the VAR model is invariant to the amount of information being impounded, as measured by the change in price. Perhaps the price discovery process is flexible and accelerates or decelerates in response to information flow. The passive order return CIRFs mirror those of the active trades, rising in importance as liquidity falls.

Of concern is the ability to pre-select the VAR model outcome by choosing the stocks included in a study, given their wide-ranging return CIRFs. If an author had an end goal in mind (VAR model shows a lot of information impounding with high return CIRFs, or very little information impounding with low return CIRFs), an appropriate group of stocks could be selected. For

example, if the goal was to support information impounding in the morning subperiod, stocks from Group 4 could be chosen.

Table 3.32: Bid Return CIRFs for VAR Model 1 with Alternate Subgroups

This table reports the average bid return CIRFs for VAR Model 1 using the alternative subgroups based on liquidity. Columns 2 through 6 present the average bid return CIRFs for the order impulse in the column header (for example, the order impulse in column 2 is a *Trade*, and in column 3 a *Change to Existing Bid*). Average CIRFs are reported for each subperiod, with each liquidity defined subgroup's CIRFs presented in separate panels. For example, the bid return CIRF for a *Trade* impulse in VAR Model 1 on March 18th during the day is 0.017% for Group 1 stocks. The Midpoint price changes over each subperiod for each alternative subgroup are included in the first column for reference. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Average Return CIRFs for given impulse - Group 1						
March 18	Midpoint % Change	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	6.886%	0.017%	0.005%	0.030%	-0.005%	0.007%
		0.0	0.0	0.0	0.0	0.0
Morning	-1.404%	0.019%	0.006%	0.044%	-0.004%	0.006%
		0.0	0.0	0.0	0.0	0.0
Pre	0.560%	0.016%	0.004%	0.033%	-0.004%	0.007%
		0.0	0.0	0.01	0.0	0.0
Post	7.806%	0.017%	0.005%	0.030%	-0.007%	0.009%
		0.0	0.0	0.0	0.0	0.0
March 19						
Day	-1.492%	0.014%	0.004%	0.028%	-0.005%	0.007%
		0.0	0.0	0.0	0.01	0.0
Morning	-1.601%	0.016%	0.005%	0.031%	-0.006%	0.007%
		0.0	0.0	0.0	0.01	0.0
Pre	0.051%	0.013%	0.003%	0.037%	-0.005%	0.009%
		0.0	0.0	0.0	0.0	0.0
Post	0.036%	0.012%	0.003%	0.025%	-0.004%	0.007%
		0.0	0.0	0.0	0.02	0.0
Average Return CIRFs for given impulse - Group 2						
March 18	Midpoint % Change	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	0.824%	0.042%	0.013%	0.065%	-0.012%	0.019%
		0.0	0.0	0.0	0.0	0.0
Morning	-1.324%	0.041%	0.012%	0.068%	-0.010%	0.017%
		0.0	0.0	0.0	0.0	0.0
Pre	0.715%	0.034%	0.011%	0.071%	-0.009%	0.014%
		0.0	0.0	0.0	0.0	0.0
Post	1.454%	0.047%	0.016%	0.070%	-0.017%	0.022%
		0.0	0.0	0.0	0.0	0.0
March 19						
Day	-0.172%	0.033%	0.011%	0.062%	-0.010%	0.013%
		0.0	0.0	0.0	0.0	0.0
Morning	0.547%	0.038%	0.014%	0.065%	-0.012%	0.015%
		0.0	0.0	0.0	0.0	0.0
Pre	0.461%	0.030%	0.009%	0.063%	-0.010%	0.013%

		0.0	0.0	0.0	0.0	0.0
Post	-1.181%	0.028%	0.009%	0.065%	-0.009%	0.013%
		0.0	0.0	0.0	0.0	0.0

Average Return CIRFs for given impulse - Group 3

March 18	Midpoint % Change	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	1.120%	0.053%	0.023%	0.088%	-0.015%	0.020%
		0.0	0.0	0.0	0.0	0.0
Morning	-1.048%	0.063%	0.025%	0.103%	-0.016%	0.019%
		0.0	0.0	0.0	0.0	0.0
Pre	0.927%	0.040%	0.021%	0.102%	-0.010%	0.012%
		0.0	0.01	0.0	0.01	0.06
Post	1.255%	0.053%	0.022%	0.086%	-0.014%	0.021%
		0.0	0.0	0.0	0.01	0.0
March 19						
Day	-3.653%	0.047%	0.016%	0.077%	-0.016%	0.016%
		0.0	0.0	0.0	0.0	0.0
Morning	-1.779%	0.059%	0.017%	0.086%	-0.020%	0.020%
		0.0	0.0	0.0	0.0	0.0
Pre	-0.602%	0.044%	0.016%	0.091%	-0.013%	0.010%
		0.0	0.0	0.0	0.01	0.0
Post	-1.330%	0.034%	0.012%	0.075%	-0.012%	0.013%
		0.0	0.0	0.0	0.0	0.0

Average Return CIRFs for given impulse - Group 4

March 18	Midpoint % Change	Trade Impulse	Change to Existing Bid Impulse	New Bid Impulse	Change to Existing Ask Impulse	New Ask Impulse
Day	1.472%	0.106%	0.044%	0.161%	-0.016%	0.033%
		0.0	0.0	0.0	0.0	0.0
Morning	-0.417%	0.120%	0.046%	0.189%	-0.013%	0.031%
		0.0	0.0	0.0	0.0	0.0
Pre	0.745%	0.075%	0.028%	0.177%	-0.008%	0.020%
		0.0	0.0	0.0	0.03	0.0
Post	1.158%	0.106%	0.036%	0.187%	-0.015%	0.029%
		0.0	0.0	0.0	0.0	0.0
March 19						
Day	-1.060%	0.084%	0.031%	0.138%	-0.021%	0.030%
		0.0	0.0	0.0	0.0	0.0
Morning	-0.920%	0.109%	0.040%	0.156%	-0.020%	0.033%
		0.0	0.0	0.0	0.0	0.0
Pre	0.031%	0.079%	0.022%	0.181%	-0.014%	0.023%
		0.0	0.0	0.0	0.0	0.0
Post	-0.122%	0.053%	0.020%	0.154%	-0.010%	0.024%
		0.0	0.0	0.0	0.0	0.0

For brevity, the alternate group impact on the trade flow categories is represented by the VAR Model 4 results in Table 3.33. The more liquid groups have higher return CIRFs for *Non-Inflection* trades than *Inflection* trades, but as liquidity falls the price impact of *Inflection* trades rises relative to *Non-Inflection* trades and is more influential in Group 4. This is consistent with the contrarian trading literature that a lack of liquidity provides a trading opportunity for contrarian

traders to bet on mean reversion. *Equal To* trades are the most influential trades for all of the alternate subgroups, reinforcing their signalling importance regardless of liquidity, but perhaps still raising the question as to how stealthy these trades are if they are consistently identifiable. Interestingly, the *Greater Than* trades have similar price impact as *Less Than* trades for liquid stocks (Groups 1 and 2) but become more important for price impact as liquidity falls and perhaps have more direct effect on the limit order book.

Table 3.33: Bid Return CIRFs for VAR Model 4 Trade Impulses

The table below presents the average bid return CIRFs for *Inflection Greater Than, Inflection Equal To, Inflection Less Than*, *Non-Inflection Greater Than, Non-Inflection Equal To*, and *Non-Inflection Less Than* trades, broken down by subperiod and alternative subgroup. Column 1, for example, reports an average bid return CIRF of 0.014% for an *Inflection Greater Than* trade impulse in the day subperiod of March 18th for Group 1 stocks. Average return CIRFs for *Inflection Equal To* and *Inflection Less Than* trade impulses are presented in columns 2 and 3, with columns 4 through 6 reporting the *Non-Inflection Greater Than, Non-Inflection Equal To*, and *Non-Inflection Less Than* return CIRFs. Group 1, Group 2, Group 3, and Group 4 results are reported in separate panels. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

		Return CIRFs for given impulse - Group 1					
March 18	Midpoint % Change	Inflection Greater Than Impulse	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection Greater Than Impulse	Non-Inflection Equal To Impulse	Non-Inflection Less Than Impulse
Day	6.886%	0.014% 0.0	0.023% 0.0	0.008% 0.0	0.015% 0.0	0.029% 0.0	0.015% 0.0
Morning	-1.404%	0.017% 0.0	0.028% 0.0	0.008% 0.0	0.017% 0.0	0.031% 0.0	0.016% 0.0
Pre	0.560%	0.014% 0.0	0.026% 0.0	0.007% 0.0	0.016% 0.0	0.026% 0.0	0.012% 0.0
Post	7.806%	0.014% 0.0	0.022% 0.0	0.008% 0.0	0.014% 0.0	0.032% 0.0	0.015% 0.0
March 19							
Day	-1.492%	0.012% 0.0	0.018% 0.0	0.006% 0.01	0.013% 0.0	0.024% 0.0	0.012% 0.0
Morning	-1.601%	0.013% 0.0	0.020% 0.0	0.008% 0.02	0.014% 0.0	0.027% 0.0	0.013% 0.0
Pre	0.051%	0.011% 0.0	0.017% 0.0	0.007% 0.0	0.015% 0.0	0.021% 0.0	0.011% 0.0
Post	0.036%	0.010% 0.0	0.018% 0.0	0.005% 0.03	0.010% 0.0	0.022% 0.0	0.009% 0.0

		Return CIRFs for given impulse - Group 2					
March 18	Midpoint % Change	Inflection Greater	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection	Non-Inflection	Non-Inflection

		Than Impulse			Greater Than Impulse	Equal To Impulse	Less Than Impulse
Day	0.824%	0.033%	0.062%	0.027%	0.033%	0.067%	0.034%
		0.0	0.0	0.0	0.0	0.0	0.0
Morning	-1.324%	0.032%	0.056%	0.025%	0.035%	0.063%	0.032%
		0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.715%	0.033%	0.051%	0.017%	0.029%	0.051%	0.025%
		0.0	0.0	0.0	0.0	0.0	0.0
Post	1.454%	0.034%	0.080%	0.035%	0.034%	0.082%	0.040%
		0.0	0.0	0.0	0.0	0.0	0.0
March 19							
Day	-0.172%	0.025%	0.048%	0.020%	0.028%	0.057%	0.026%
		0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.547%	0.026%	0.055%	0.022%	0.032%	0.067%	0.030%
		0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.461%	0.022%	0.040%	0.016%	0.026%	0.047%	0.025%
		0.0	0.0	0.0	0.0	0.0	0.0
Post	-1.181%	0.028%	0.047%	0.017%	0.022%	0.049%	0.024%
		0.0	0.0	0.0	0.0	0.0	0.0

Return CIRFs for given impulse - Group 3

March 18	Midpoint % Change	Inflection Greater Than Impulse	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection Greater Than Impulse	Non-Inflection Equal To Impulse	Non-Inflection Less Than Impulse
Day	1.120%	0.047%	0.088%	0.040%	0.040%	0.075%	0.047%
		0.0	0.0	0.0	0.01	0.0	0.0
Morning	-1.048%	0.047%	0.100%	0.043%	0.050%	0.097%	0.049%
		0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.927%	0.033%	0.052%	0.021%	0.041%	0.051%	0.020%
		0.0	0.0	0.01	0.0	0.0	0.02
Post	1.255%	0.047%	0.097%	0.034%	0.037%	0.072%	0.048%
		0.0	0.0	0.0	0.01	0.0	0.0
March 19							
Day	-3.653%	0.039%	0.061%	0.036%	0.038%	0.070%	0.041%
		0.0	0.0	0.0	0.0	0.0	0.0
Morning	-1.779%	0.046%	0.072%	0.046%	0.049%	0.078%	0.048%
		0.0	0.0	0.01	0.01	0.0	0.0
Pre	-0.602%	0.033%	0.055%	0.018%	0.033%	0.056%	0.029%
		0.0	0.0	0.0	0.02	0.0	0.01
Post	-1.330%	0.035%	0.047%	0.015%	0.032%	0.060%	0.022%
		0.0	0.0	0.0	0.02	0.0	0.01

Return CIRFs for given impulse - Group 4

March 18	Midpoint % Change	Inflection Greater Than Impulse	Inflection Equal To Impulse	Inflection Less Than Impulse	Non-Inflection Greater Than Impulse	Non-Inflection Equal To Impulse	Non-Inflection Less Than Impulse
Day	1.472%	0.096%	0.141%	0.058%	0.068%	0.116%	0.050%
		0.0	0.0	0.0	0.0	0.0	0.0
Morning	-0.417%	0.107%	0.208%	0.059%	0.106%	0.138%	0.043%
		0.0	0.0	0.0	0.0	0.0	0.0
Pre	0.745%	0.064%	0.108%	0.017%	0.066%	0.083%	0.027%
		0.0	0.0	0.06	0.04	0.0	0.0
Post	1.158%	0.074%	0.139%	0.056%	0.078%	0.109%	0.051%
		0.0	0.0	0.0	0.0	0.0	0.0
March 19							
Day	-1.060%	0.074%	0.125%	0.019%	0.069%	0.126%	0.049%
		0.0	0.0	0.30	0.0	0.0	
Morning	-0.920%	0.098%	0.168%	0.022%	0.081%	0.173%	0.075%
		0.0	0.0	0.48	0.0	0.0	0.0
Pre	0.031%	0.066%	0.140%	0.034%	0.100%	0.114%	0.007%
		0.0	0.0	0.05	0.0	0.0	0.75
Post	-0.122%	0.051%	0.101%	0.018%	0.057%	0.079%	0.021%
		0.0	0.0	0.0	0.0	0.0	0.0

Table 3.34 shows the order flow CIRFs for the alternate subgroups and includes only one trade impulse (*Inflection Equal To* trade Impulse) as the general observations are the same for all trade impulses. The most noticeable change between subgroups is the increasing/decreasing reaction of active/passive order flow as liquidity falls from Group 1 to Group 4. More liquid stocks see most of the trade impulse reaction in passive order flow, while less liquid stocks have most of their endogenous order flow in the form of active trades. Early literature that concluded that active trades contained information while passive orders were uninformed is consistent with the VAR model results for the alternate subgroups' follow-on order flow, but these conclusions are contradicted by midpoint price changes for each subgroup. It is tough to reconcile the most liquid stocks simultaneously having the least amount of information impounding and larges price moves. Somehow, the largest, most influential stocks have the fewest informed traders, or maybe those traders have the least impact on prices because of the liquidity, which begs the question, how can an information measurement model be relied upon if it is so susceptible to variations in liquidity?

Table 3.34: Order Flow CIRFs for VAR Model 4 *Inflection* Equal To Trade Impulse

This table reports the average *Inflection Greater Than*, *Inflection Equal To*, *Inflection Less Than, Non-Inflection Greater Than*, *Non-Inflection Equal To*, *Non-Inflection Less Than*, *Change to Existing Bid*, *New Bid*, *Change to Existing Ask*, and *New Ask* trade order flow CIRFs for VAR Model 4 from an *Inflection Equal To* trade impulse, broken down by subperiod and subgroup. The table presents only the endogenous order flow response from the *Inflection Equal To* trade impulse. For example, the *Inflection Equal To* trade order flow CIRF of -13 shares (i.e. sell 13 shares) for the day of March 18th for Group 1 stocks in column 2 does not include the initial 1,000 share *Inflection Equal To* trade impulse and represents only the follow-on *Inflection Equal To* trade activity. The other order flow CIRFs in columns 1, and 3 through 10 are solely the result of their endogenous responses. For example, the *Inflection Greater Than* trade response of -23 shares (i.e. sell 23 shares) for the day subperiod on March 18th in column 1 Group 1 stocks is entirely endogenous. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	CIRFs for 1,000 Equal To Inflection Trade impulse - Group 1									
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-23	-13	-37	60	49	78	251	70	-223	49

	0.03	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.02
Morning	-20	-13	-35	56	39	79	269	73	-298	58
	0.16	0.01	0.0	0.01	0.0	0.01	0.0	0.0	0.0	0.02
Pre	-12	-12	-30	56	46	64	263	67	-300	80
	0.18	0.01	0.0	0.06	0.01	0.03	0.0	0.0	0.01	0.0
Post	-36	-16	-42	57	51	81	246	80	-202	48
	0.02	0.01	0.01	0.0	0.0	0.0	0.0	0.02	0.0	0.04
March 19										
Day	-5	-12	-26	42	32	63	363	44	-235	35
	0.43	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
Morning	-8	-15	-29	47	36	70	337	40	-213	27
	0.52	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Pre	-4	-7	-20	28	26	47	410	53	-291	39
	0.20	0.0	0.0	0.01	0.01	0.01	0.01	0.0	0.03	0.01
Post	-10	-10	-26	41	21	68	395	56	-293	51
	0.41	0.15	0.0	0.01	0.01	0.06	0.0	0.03	0.0	0.04

CIRFs for 1,000 Equal To Inflection Trade impulse - Group 2

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-21	-25	-55	77	75	114	240	83	-265	86
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morning	-22	-25	-52	74	72	112	213	62	-229	66
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pre	-22	-20	-34	33	45	88	192	83	-350	85
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Post	-22	-29	-64	79	81	115	250	118	-293	105
	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March 19										
Day	-11	-26	-42	68	69	90	234	81	-246	87
	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morning	-11	-29	-45	80	74	102	192	88	-170	41
	0.16	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0
Pre	-9	-21	-30	37	59	73	251	70	-265	80
	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Post	-14	-20	-40	62	59	86	310	71	-342	165
	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06

CIRFs for 1,000 Equal To Inflection Trade impulse - Group 3

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-69	-48	-84	209	157	196	165	121	-87	79
	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.37	0.16
Morning	-73	-47	-81	151	142	181	2	83	-153	135
	0.0	0.0	0.0	0.01	0.01	0.01	0.95	0.0	0.0	0.0
Pre	-1	-39	-40	142	90	128	137	36	-81	44
	0.99	0.0	0.01	0.21	0.12	0.03	0.05	0.23	0.42	0.05
Post	-9	-34	-109	182	126	133	266	194	-136	42
	0.82	0.0	0.0	0.02	0.0	0.0	0.03	0.04	0.29	0.57
March 19										
Day	-112	-29	-67	137	108	107	144	89	-109	76
	0.01	0.02	0.0	0.08	0.0	0.01	0.17	0.02	0.24	0.01
Morning	-127	-39	-49	124	77	129	137	116	-7	18
	0.01	0.01	0.0	0.12	0.01	0.0	0.14	0.0	0.90	0.57
Pre	-101	-8	-98	114	87	17	319	77	-266	84
	0.03	0.62	0.01	0.04	0.0	0.83	0.14	0.01	0.32	0.03
Post	-42	-19	-53	169	84	87	36	25	-106	57
	0.14	0.02	0.0	0.23	0.02	0.02	0.67	0.70	0.23	0.07

CIRFs for 1,000 Equal To Inflection Trade impulse - Group 4

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection	Non-Inflection Equal To	Non-Inflection Less Than	Change to	New Bid	Change to	New Ask

				Greater Than			Existing Bid		Existing Ask	
Day	-101	-34	-43	96	98	109	92	88	-70	127
	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morning	-124	-17	-35	109	95	74	46	81	-98	80
	0.20	0.01	0.0	0.02	0.0	0.0	0.18	0.0	0.04	0.02
Pre	-24	-16	-26	76	52	90	24	34	-63	99
	0.07	0.0	0.0	0.0	0.0	0.0	0.66	0.08	0.01	0.0
Post	-25	-27	-30	41	61	65	131	51	-59	101
	0.13	0.0	0.0	0.08	0.0	0.0	0.0	0.02	0.02	0.0
March 19										
Day	-7	-29	-67	100	115	105	63	59	-64	95
	0.67	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.02	0.0
Morning	-30	-22	-80	89	115	119	40	23	-48	95
	0.05	0.01	0.03	0.0	0.0	0.0	0.28	0.73	0.25	0.0
Pre	-80	-23	-33	54	145	69	-8	88	-81	41
	0.07	0.02	0.0	0.09	0.04	0.0	0.89	0.05	0.29	0.14
	15	-9	-30	82	53	38	47	5	-27	47
	0.49	0.47	0.0	0.0	0.0	0.0	0.18	0.75	0.50	0.02

Without reproducing all of the results from section 3.4, the results for the alternate subgroups draw the conclusion that the VAR model information measure is sensitive to the choice of stocks used in the calculations. Since information measuring literature relies on averaging results across a group of stocks, the influence of stock selection on the results is meaningful and could be a significant driver of reported results. The alternate subgroups expose the strata of results which are obscured by shallower divisions and highlight the possibility that the VAR model does not accurately measure information.

3.6: Conclusions

Chapter 3 expands on the insights from Chapter 2 and seeks deeper understanding of the price discovery mechanics influencing information impounding and the VAR model CIRFs. The primary objective is to expand our understanding of the impact of trading patterns, passive order flow, and liquidity on information flow into stock prices. To achieve these objectives, four new VAR models are formulated that add passive order flow (VAR Model 1), passive order flow with *Inflection* and *Non-Inflection* trades (VAR Model 2), passive order flow with *Greater Than*, *Equal To*, and *Less Than* trades (VAR Model 3), and passive order flow with *Inflection* and *Non-Inflection* versions of *Greater Than*, *Equal To*, and *Less Than* trades (VAR Model 4). The analysis of these VAR models contributes to the literature by quantifying the impact of passive order flow and trading patterns on information impounding in the VAR model CIRFs, while uncovering the trade

and order flow mechanisms for stock prices. The liquidity analysis raises questions about the type of information measured by the VAR model, leading directly to the analysis in Chapter 4.

VAR Model 1 illustrates the information content of passive orders, which has been ignored until recently (Brogaard et al., 2019), while expanding the literature by using a new set of passive order variables that allow CIRFs to be calculated for passive order flow. The analysis concludes that certain passive order flow variables are at least as influential on prices as active trades, and the information content of active trades, as measured by the VAR model, is reduced when passive orders are included. *Trades* have been credited with information that is more properly attributed to passive order flow. Trading patterns that are not typically covered in the literature are shown to determine the return CIRFs in VAR Models 2, 3, and 4, adding to the literature by concluding that these trading pattern variables should be included in the VAR model. The expanded set of variables identified in this Chapter could help explain the VAR Model information failings identified by Collin-Dufresne and Fos (2015) who find lower VAR Model information measures when informed traders are known to be active in the market. A unique contribution to the literature is made by the decomposition of the return and order CIRFs to show how trade and order flow variables interact in the price discovery process. The order flow CIRF decomposition, for example, uncovers informed and uninformed endogenous trading activity that feeds into the return CIRFs, complicating the interpretation of price impact (i.e. we may be interpreting price change as informed when the endogenous trading activity indicates the market interprets the impulse as uninformed). Different stock subgroups experience different endogenous reactions, which could mean there are different price formation mechanisms in the market. If we rely on models that ignore this complexity, perhaps by depending only on positively correlated trade and return sequences, we may not be producing accurate estimates of information flow into prices. The alternate subgroups analysis provides evidence that VAR is not measuring information related to net price change, but rather liquidity, which could indicate that information impounding depends on liquidity and may correlate with volume such that more/less liquid stocks have higher/lower information processing throughput which affects the VAR model return CIRFs. If the alternate subgroup interpretation is correct, price movements could be counter to

the return CIRFs if price changes caused by illiquidity are a new trading pattern that influences the VAR model like the new trade variables introduced to the VAR model in this Chapter.

3.7: Chapter 3 References

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3.8: Chapter 3 Appendix

Appendix 3.1: Proportion of Bid and Ask Price Changes

The table contains the average proportion of all price changes in which there is a change in both the bid and ask prices (Bid and Ask) in the same tick for the Cross-Listed, Non-Cross-Listed, and alternate subgroups.

March 18	Cross-Listed	Non-Cross-Listed	Group 1	Group 2	Group 3	Group 4
Day	5.6%	5.9%	9.4%	6.0%	5.1%	5.1%
Morning	5.9%	5.7%	9.6%	6.5%	5.1%	4.9%
Pre	7.3%	6.5%	10.8%	8.2%	5.5%	6.0%
Post	5.0%	6.2%	8.9%	5.1%	5.3%	5.2%
March 19						
Day	5.5%	5.7%	9.0%	5.4%	4.9%	5.2%
Morning	5.0%	5.3%	8.5%	5.0%	4.2%	4.8%
Pre	6.2%	6.5%	9.2%	6.4%	5.5%	5.9%
Post	6.9%	7.2%	11.7%	6.7%	6.4%	6.5%

Appendix 3.2: VAR Model 1 Ask Return CIRF Breakdown for Trade, Change to Existing Bid and New Bid Impulses

Ask Return CIRF breakdown for 1,000 share Trade Impulse

Ask Price CIRF for 1,000 Trade impulse by component - Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0759%	0.0920%	0.0010%	0.0000%	0.0126%	0.0011%	0.0054%	-0.0361%
Morning	0.0715%	0.0864%	0.0008%	0.0002%	0.0120%	0.0007%	0.0027%	-0.0311%
Pre	0.0756%	0.0884%	0.0004%	0.0006%	0.0070%	0.0015%	0.0032%	-0.0253%
Post	0.0778%	0.0857%	0.0011%	0.0002%	0.0107%	0.0013%	0.0072%	-0.0282%
March 19								
Day	0.0488%	0.0557%	0.0006%	0.0000%	0.0083%	0.0008%	0.0036%	-0.0202%
Morning	0.0681%	0.0840%	0.0004%	0.0003%	0.0093%	0.0008%	0.0039%	-0.0306%
Pre	0.0417%	0.0409%	0.0004%	-0.0001%	0.0060%	0.0008%	0.0039%	-0.0103%
Post	0.0358%	0.0377%	0.0005%	-0.0001%	0.0053%	0.0006%	0.0033%	-0.0114%

Ask Price CIRF for 1,000 Trade impulse by component - Non-Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0755%	0.0860%	0.0010%	0.0011%	0.0076%	-0.0001%	0.0092%	-0.0294%
Morning	0.0826%	0.0861%	0.0009%	0.0008%	0.0111%	0.0004%	0.0160%	-0.0326%
Pre	0.0562%	0.0582%	0.0006%	0.0010%	0.0034%	-0.0003%	0.0028%	-0.0096%
Post	0.0752%	0.0858%	0.0007%	0.0011%	0.0048%	0.0000%	0.0082%	-0.0253%
March 19								
Day	0.0678%	0.0750%	0.0003%	0.0005%	0.0084%	0.0005%	0.0086%	-0.0255%
Morning	0.0828%	0.0932%	0.0002%	0.0010%	0.0076%	0.0008%	0.0089%	-0.0288%
Pre	0.0644%	0.0699%	0.0003%	0.0007%	0.0052%	0.0003%	0.0047%	-0.0167%
Post	0.0512%	0.0578%	0.0001%	0.0010%	0.0043%	0.0001%	0.0046%	-0.0167%

Ask Return CIRF breakdown for 1,000 share Change to Existing Bid

Ask Price CIRF for 1,000 Change to Existing Bid impulse by component - Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0118%	0.0013%	0.0104%	0.0001%	0.0042%	0.0006%	0.0005%	-0.0053%
Morning	0.0086%	0.0017%	0.0060%	0.0006%	0.0029%	0.0004%	0.0009%	-0.0039%
Pre	0.0093%	0.0005%	0.0080%	-0.0002%	0.0023%	0.0004%	0.0010%	-0.0027%
Post	0.0127%	0.0024%	0.0063%	0.0004%	0.0035%	0.0006%	0.0042%	-0.0048%
March 19								
Day	0.0081%	0.0007%	0.0075%	-0.0005%	0.0025%	0.0004%	0.0009%	-0.0034%
Morning	0.0099%	0.0019%	0.0123%	-0.0023%	0.0032%	0.0007%	-0.0016%	-0.0043%
Pre	0.0064%	-0.0001%	0.0046%	0.0000%	0.0015%	0.0003%	0.0020%	-0.0020%
Post	0.0065%	0.0006%	0.0044%	0.0002%	0.0015%	0.0004%	0.0011%	-0.0017%

Ask Price CIRF for 1,000 Change to Existing Bid impulse by component - Non-Cross-listed Stocks								
	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
March 18								
Day	0.0222%	0.0056%	0.0284%	0.0047%	0.0040%	-0.0011%	-0.0105%	-0.0088%
Morning	0.0231%	0.0022%	0.0429%	0.0011%	0.0062%	-0.0021%	-0.0153%	-0.0118%
Pre	0.0127%	0.0044%	0.0122%	0.0024%	0.0018%	-0.0004%	-0.0054%	-0.0024%
Post	0.0157%	0.0058%	0.0127%	0.0035%	0.0020%	-0.0006%	-0.0022%	-0.0055%
March 19								
Day	0.0093%	0.0001%	0.0248%	0.0066%	0.0027%	-0.0019%	-0.0190%	-0.0040%
Morning	0.0052%	-0.0010%	0.0208%	0.0069%	0.0025%	-0.0007%	-0.0208%	-0.0025%
Pre	0.0072%	0.0008%	0.0178%	0.0033%	0.0012%	-0.0019%	-0.0127%	-0.0015%
Post	0.0071%	0.0027%	0.0168%	0.0050%	0.0013%	-0.0026%	-0.0140%	-0.0022%

Ask Return CIRF breakdown for 1,000 share New Bid

Ask Price CIRF for 1,000 New Bid impulse by component - Cross-listed Stocks								
	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
March 18								
Day	0.0936%	0.0010%	0.0034%	0.1266%	-0.0420%	0.0002%	0.0002%	0.0041%
Morning	0.1121%	-0.0011%	0.0017%	0.1540%	-0.0457%	0.0002%	0.0001%	0.0031%
Pre	0.1145%	-0.0009%	0.0028%	0.1410%	-0.0312%	0.0002%	0.0002%	0.0026%
Post	0.0983%	0.0004%	0.0026%	0.1314%	-0.0410%	0.0005%	0.0002%	0.0042%
March 19								
Day	0.0861%	-0.0009%	0.0016%	0.1115%	-0.0294%	0.0004%	0.0000%	0.0029%
Morning	0.1019%	0.0001%	0.0009%	0.1333%	-0.0364%	0.0006%	-0.0001%	0.0034%
Pre	0.0954%	-0.0021%	0.0024%	0.1222%	-0.0298%	0.0005%	-0.0005%	0.0027%
Post	0.0894%	-0.0009%	0.0017%	0.1054%	-0.0192%	0.0005%	-0.0004%	0.0024%

Ask Price CIRF for 1,000 New Bid impulse by component - Non-Cross-listed Stocks								
	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
March 18								
Day	0.1472%	-0.0015%	0.0012%	0.1995%	-0.0538%	-0.0021%	-0.0012%	0.0053%
Morning	0.1663%	-0.0023%	0.0034%	0.2141%	-0.0492%	-0.0018%	-0.0032%	0.0055%
Pre	0.1464%	-0.0008%	0.0012%	0.1772%	-0.0290%	-0.0016%	0.0010%	-0.0016%
Post	0.1762%	-0.0021%	-0.0018%	0.2317%	-0.0518%	-0.0017%	-0.0008%	0.0028%
March 19								
Day	0.1220%	-0.0027%	0.0037%	0.1745%	-0.0490%	-0.0028%	-0.0038%	0.0022%
Morning	0.1289%	-0.0021%	0.0030%	0.1814%	-0.0498%	-0.0022%	-0.0029%	0.0016%
Pre	0.1717%	-0.0034%	0.0025%	0.2079%	-0.0330%	-0.0014%	-0.0022%	0.0014%
Post	0.1398%	-0.0026%	0.0034%	0.1802%	-0.0362%	-0.0035%	-0.0024%	0.0011%

Appendix 3.3: VAR Model 1 Bid Return CIRF breakdown for Change to Existing Ask and New Ask impulses

Bid Return CIRF breakdown for 1,000 share Change to Existing Ask

Bid Price CIRF for 1,000 Change to Existing Ask impulse by component - Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	-0.0201%	0.0001%	0.0000%	-0.0005%	-0.0025%	-0.0078%	-0.0174%	0.0081%
Morning	-0.0182%	-0.0015%	-0.0002%	0.0001%	-0.0018%	-0.0080%	-0.0138%	0.0070%
Pre	-0.0147%	-0.0013%	-0.0002%	-0.0001%	-0.0016%	-0.0055%	-0.0106%	0.0044%
Post	-0.0264%	-0.0010%	-0.0005%	-0.0001%	-0.0032%	-0.0116%	-0.0195%	0.0094%
March 19								
Day	-0.0162%	-0.0020%	-0.0003%	-0.0001%	-0.0022%	-0.0063%	-0.0122%	0.0069%
Morning	-0.0215%	-0.0026%	0.0000%	-0.0004%	-0.0026%	-0.0072%	-0.0187%	0.0101%
Pre	-0.0154%	-0.0013%	-0.0003%	-0.0002%	-0.0018%	-0.0054%	-0.0101%	0.0038%
Post	-0.0101%	-0.0009%	-0.0003%	0.0001%	-0.0013%	-0.0040%	-0.0068%	0.0030%

Bid Price CIRF for 1,000 Change to Existing Ask impulse by component - Non-Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	-0.0309%	-0.0007%	0.0025%	0.0015%	-0.0018%	-0.0115%	-0.0325%	0.0117%
Morning	-0.0369%	-0.0019%	0.0047%	0.0002%	-0.0013%	-0.0175%	-0.0344%	0.0133%
Pre	-0.0138%	0.0018%	0.0008%	0.0009%	-0.0003%	-0.0052%	-0.0141%	0.0024%
Post	-0.0243%	0.0014%	0.0006%	0.0008%	-0.0007%	-0.0079%	-0.0264%	0.0080%
March 19								
Day	-0.0422%	-0.0056%	0.0032%	0.0036%	-0.0032%	-0.0148%	-0.0417%	0.0162%
Morning	-0.0446%	-0.0095%	0.0023%	0.0037%	-0.0039%	-0.0085%	-0.0451%	0.0164%
Pre	-0.0386%	-0.0024%	0.0022%	0.0015%	-0.0013%	-0.0150%	-0.0330%	0.0095%
Post	-0.0267%	0.0084%	0.0027%	0.0027%	-0.0005%	-0.0147%	-0.0336%	0.0083%

Bid Return CIRF breakdown for 1,000 share New Ask

Bid Price CIRF for 1,000 New Ask impulse by component - Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.0971%	-0.0028%	0.0002%	0.0001%	0.0045%	0.0023%	0.1333%	-0.0404%
Morning	0.1031%	-0.0027%	0.0003%	-0.0001%	0.0034%	0.0019%	0.1363%	-0.0360%
Pre	0.1111%	-0.0026%	0.0000%	-0.0001%	0.0031%	0.0008%	0.1478%	-0.0377%
Post	0.1174%	-0.0040%	0.0006%	0.0001%	0.0045%	0.0035%	0.1533%	-0.0405%
March 19								
Day	0.0886%	0.0008%	0.0002%	0.0002%	0.0034%	0.0014%	0.1189%	-0.0362%
Morning	0.1000%	0.0025%	-0.0001%	0.0007%	0.0038%	0.0002%	0.1365%	-0.0435%
Pre	0.0911%	-0.0001%	-0.0001%	-0.0002%	0.0025%	0.0015%	0.1101%	-0.0227%
Post	0.0895%	-0.0013%	0.0003%	-0.0004%	0.0024%	0.0014%	0.1101%	-0.0230%

Bid Price CIRF for 1,000 New Ask impulse by component - Non-Cross-listed Stocks								
March 18	CIRF	by Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.1461%	0.0002%	-0.0022%	-0.0006%	0.0037%	0.0024%	0.1979%	-0.0552%
Morning	0.1678%	0.0012%	-0.0039%	-0.0005%	0.0049%	0.0035%	0.2179%	-0.0553%
Pre	0.1385%	-0.0024%	-0.0010%	0.0003%	0.0011%	0.0013%	0.1614%	-0.0221%
Post	0.1586%	-0.0027%	-0.0004%	-0.0003%	0.0019%	0.0014%	0.2067%	-0.0479%
March 19								
Day	0.1385%	0.0002%	-0.0023%	-0.0034%	0.0040%	0.0040%	0.1898%	-0.0536%
Morning	0.1500%	0.0024%	-0.0017%	-0.0034%	0.0039%	0.0025%	0.2006%	-0.0543%
Pre	0.1697%	-0.0083%	-0.0011%	-0.0030%	0.0006%	0.0034%	0.2183%	-0.0402%
Post	0.1358%	-0.0139%	-0.0020%	-0.0029%	0.0038%	0.0042%	0.1872%	-0.0406%

Appendix 3.4: Granger Causality Test P-Values for VAR Model 1 and VAR Model 2

Two particular caveats are important in the present context, both described by Granger himself. Since VAR Model 1 contains more than 2 independent variables, the Granger Causality may not isolate a specific feedback mechanism(Granger, 1969). Consider a model with 3 variables, *x*, *y*, and *z*. If we removed variable *x* and the remaining variables have less explanatory power, we reject the hypothesis that *x* does not Granger Cause *y* and *z*. We do not, however, know if *x* is influencing *y*, *z*, or a combination of *y* and *z*. If we then removed *y*, leaving *x* and *z* in the model, and find that we cannot reject y Granger Causing *x* and *z*, we are left with a conundrum. Since we cannot determine if *y* is explaining *x*, *z*, or *x* and *z*, we cannot rule out *x* and *y* causing each other and the possibility of instantaneous causality (i.e. that x_t and y_t are correlated), which means any measure of Granger causality loses meaning (i.e. we cannot tell "who made who"[7]). This shows up in the Granger Instantaneous Causality p-values in Appendix III, where both Bid and Ask price changes appear to have a contemporaneous impact on the model, despite the data being explicitly organized such that only one variable is observed at any point in time.

Another causality issue comes from Granger (1980). If *x* does in fact cause *y* and *z*, but there is a lag between when *x* causes a response in *y* and *z*, then *y* may appear to cause *z* (in Granger's example, *x* is not observed, but in the context of the VAR model that is synonymous with the *x* observation occurring more lags in the past than the model's order, or before *y* is observed). If an order enters the market, such as a trade or *New Bid*, part of its true impact may be masked by intermediate changes in other variables. In the case of *New Bids*, for example, the dataset contains a consistent *Change to Exiting Bid* response after a *New Bid*, which may effectively mean the intermediate variable (*Change to Existing Bid*) is accounting for some of the bid price response due to the *New Bid*. Since bid and ask prices result from a number of different causes, they are effectively inserting themselves as intermediate observations between a large number of relationships. As a comparison, we do not see this problem with the Standard VAR model,

[7] To quote AC/DC, "If you made them and they made you, who picked up the bill and who made who?", from the eponymously named song, "Who Made Who".

which contains only two time series. Untangling the true source of implied causation is difficult for the Granger tests.

VAR Model 1

Null Hypothesis = Variable Does Not Granger Cause, Cross-listed Stocks

March 18	Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Morning	0.00	0.06	0.00	0.01	0.05	0.00	0.01
Pre	0.00	0.04	0.00	0.01	0.03	0.00	0.00
Post	0.00	0.01	0.00	0.00	0.00	0.00	0.01
March 19							
Day	0.00	0.04	0.00	0.01	0.00	0.00	0.00
Morning	0.00	0.06	0.00	0.02	0.00	0.00	0.00
Pre	0.00	0.02	0.00	0.00	0.01	0.00	0.00
Post	0.00	0.06	0.00	0.00	0.01	0.00	0.02

Null Hypothesis = Variable Does Not Granger Cause, Non-Cross-listed Stocks

March 18	Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.00	0.01	0.00	0.01	0.06	0.00	0.00
Morning	0.00	0.05	0.00	0.04	0.09	0.00	0.09
Pre	0.00	0.17	0.00	0.07	0.20	0.00	0.11
Post	0.00	0.10	0.00	0.05	0.16	0.00	0.03
March 19							
Day	0.00	0.03	0.00	0.01	0.00	0.00	0.01
Morning	0.00	0.12	0.00	0.07	0.02	0.00	0.03
Pre	0.00	0.20	0.00	0.07	0.05	0.00	0.04
Post	0.00	0.22	0.00	0.04	0.18	0.00	0.11

Null Hypothesis = Variable Does Not Instantaneously Granger Cause, Cross-listed Stocks

March 18	Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.13	0.47	0.22	0.02	0.40	0.18	0.02
Morning	0.21	0.67	0.52	0.04	0.59	0.44	0.04
Pre	0.36	0.52	0.45	0.08	0.55	0.47	0.06
Post	0.21	0.56	0.31	0.03	0.54	0.31	0.03
March 19							
Day	0.23	0.36	0.29	0.02	0.38	0.30	0.02
Morning	0.39	0.55	0.48	0.01	0.54	0.44	0.02
Pre	0.42	0.50	0.40	0.09	0.48	0.45	0.10
Post	0.38	0.42	0.36	0.04	0.43	0.44	0.07

Null Hypothesis = Variable Does Not Instantaneously Granger Cause, Non-Cross-listed Stocks

March 18	Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.55	0.71	0.55	0.12	0.84	0.59	0.15
Morning	0.80	0.85	0.75	0.27	0.90	0.66	0.28
Pre	0.82	0.87	0.74	0.44	0.92	0.77	0.42
Post	0.75	0.87	0.76	0.28	0.91	0.79	0.31
March 19							
Day	0.75	0.63	0.55	0.15	0.66	0.53	0.16
Morning	0.83	0.80	0.67	0.26	0.79	0.67	0.26
Pre	0.88	0.82	0.77	0.45	0.83	0.75	0.46
Post	0.92	0.81	0.70	0.36	0.85	0.71	0.36

VAR Model 2

Null Hypothesis = Variable Does Not Granger Cause, Cross-listed Stocks

March 18	Inflection Trade Do Not	Non-Inflection Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Morning	0.00	0.00	0.05	0.00	0.00	0.04	0.00	0.00
Pre	0.00	0.00	0.05	0.00	0.01	0.03	0.00	0.00
Post	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
March 19								
Day	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00
Morning	0.01	0.00	0.06	0.00	0.04	0.01	0.00	0.00
Pre	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00
Post	0.00	0.00	0.06	0.00	0.00	0.01	0.00	0.02

Null Hypothesis = Variable Does Not Granger Cause, Non-Cross-listed Stocks

March 18	Inflection Trade Do Not	Non-Inflection Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.01
Morning	0.00	0.00	0.03	0.00	0.09	0.05	0.00	0.11
Pre	0.03	0.01	0.15	0.00	0.08	0.21	0.00	0.10
Post	0.01	0.00	0.10	0.00	0.05	0.14	0.00	0.04
March 19								
Day	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.01
Morning	0.03	0.00	0.11	0.00	0.07	0.02	0.00	0.06
Pre	0.05	0.02	0.22	0.00	0.08	0.06	0.00	0.05
Post	0.00	0.00	0.23	0.00	0.11	0.17	0.00	0.13

Null Hypothesis = Variable Does Not Instantaneously Granger Cause, Cross-listed Stocks

March 18	Inflection Trade Do Not	Non-Inflection Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.50	0.08	0.44	0.24	0.02	0.40	0.21	0.02
Morning	0.77	0.15	0.67	0.56	0.05	0.60	0.47	0.04
Pre	0.83	0.20	0.54	0.49	0.07	0.57	0.50	0.05
Post	0.73	0.17	0.56	0.34	0.03	0.55	0.34	0.03
March 19								
Day	0.67	0.15	0.38	0.31	0.02	0.37	0.32	0.03
Morning	0.80	0.29	0.56	0.51	0.02	0.54	0.47	0.03
Pre	0.91	0.32	0.52	0.43	0.09	0.49	0.48	0.10
Post	0.84	0.25	0.45	0.39	0.03	0.44	0.46	0.06

Null Hypothesis = Variable Does Not Instantaneously Granger Cause, Non-Cross-listed Stocks

March 18	Inflection Trade Do Not	Non-Inflection Trade Do Not	Change to Existing Bid Do Not	New Bid Do Not	Bid Price Change Do Not	Change to Existing Ask Do Not	New Ask Do Not	Ask Price Change Do Not
Day	0.92	0.38	0.72	0.55	0.12	0.87	0.62	0.13
Morning	0.95	0.65	0.87	0.78	0.29	0.93	0.70	0.29
Pre	0.95	0.75	0.90	0.77	0.46	0.94	0.79	0.44
Post	0.98	0.62	0.88	0.77	0.30	0.93	0.82	0.31
March 19								
Day	0.91	0.48	0.68	0.57	0.16	0.69	0.56	0.18
Morning	0.93	0.68	0.83	0.71	0.27	0.81	0.70	0.27
Pre	0.95	0.75	0.85	0.80	0.43	0.84	0.79	0.44
Post	0.97	0.78	0.85	0.73	0.41	0.89	0.73	0.39

Appendix 3.5: VAR Model 2 Return CIRFs for Active and Passive Trade Impulses

	Return CIRFs for given impulse - Cross-listed						
	Midpoint % Change	1,000 Share Inflection Trade	1,000 Share Non-Inflection Trade	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
March 18							
Day	2.133%	0.064%	0.068%	0.021%	0.094%	-0.013%	0.022%
		0.069%	0.081%	0.012%	0.020%	-0.020%	0.097%
Morning	-0.782%	0.065%	0.082%	0.018%	0.114%	-0.009%	0.019%
		0.062%	0.082%	0.009%	0.018%	-0.018%	0.104%
Pre	0.686%	0.053%	0.056%	0.017%	0.116%	-0.010%	0.017%
		0.075%	0.076%	0.009%	0.019%	-0.015%	0.111%
Post	2.244%	0.072%	0.070%	0.022%	0.098%	-0.017%	0.026%
		0.068%	0.085%	0.012%	0.021%	-0.026%	0.118%
March 19							
Day	-0.741%	0.045%	0.051%	0.015%	0.086%	-0.011%	0.018%
		0.048%	0.051%	0.008%	0.013%	-0.016%	0.089%
Morning	-0.417%	0.055%	0.069%	0.022%	0.102%	-0.011%	0.021%
		0.066%	0.072%	0.010%	0.014%	-0.021%	0.100%
Pre	0.344%	0.048%	0.044%	0.011%	0.097%	-0.011%	0.015%
		0.044%	0.044%	0.007%	0.014%	-0.015%	0.091%
Post	-0.667%	0.035%	0.033%	0.010%	0.090%	-0.008%	0.012%
		0.037%	0.037%	0.007%	0.014%	-0.011%	0.089%

	Return CIRFs for given impulse – Non-Cross-listed						
	Midpoint % Change	1,000 Share Inflection Trade	1,000 Share Non-Inflection Trade	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
March 18							
Day	1.319%	0.097%	0.082%	0.041%	0.148%	-0.015%	0.029%
		0.075%	0.079%	0.022%	0.026%	-0.031%	0.146%
Morning	-0.849%	0.112%	0.089%	0.045%	0.161%	-0.016%	0.028%
		0.087%	0.076%	0.020%	0.021%	-0.036%	0.168%
Pre	0.779%	0.062%	0.054%	0.024%	0.148%	-0.001%	0.012%
		0.054%	0.058%	0.011%	0.014%	-0.010%	0.140%
Post	1.411%	0.092%	0.086%	0.030%	0.176%	-0.009%	0.021%
		0.067%	0.086%	0.015%	0.018%	-0.024%	0.158%
March 19							
Day	-1.713%	0.074%	0.082%	0.031%	0.123%	-0.023%	0.028%
		0.065%	0.075%	0.009%	0.017%	-0.041%	0.140%
Morning	-1.075%	0.091%	0.098%	0.035%	0.129%	-0.024%	0.029%
		0.085%	0.084%	0.005%	0.014%	-0.043%	0.151%
Pre	-0.297%	0.077%	0.083%	0.023%	0.169%	-0.014%	0.021%
		0.068%	0.082%	0.007%	0.017%	-0.038%	0.168%
Post	-0.354%	0.051%	0.052%	0.020%	0.142%	-0.009%	0.023%
		0.049%	0.055%	0.007%	0.018%	-0.024%	0.137%

Appendix 3.6: VAR Model 2 Bid Return CIRF Breakdown for Inflection and Non-Inflection Trade Impulses

Bid Return CIRF breakdown for 1,000 share Inflection Trade Impulse

Bid Price CIRF for 1,000 share Inflection Trade impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.064%	0.057%	0.017%	0.001%	0.004%	-0.028%	0.001%	0.000%	0.011%
Morning	0.065%	0.056%	0.021%	0.000%	0.007%	-0.028%	0.001%	0.000%	0.008%
Pre	0.053%	0.047%	0.010%	-0.001%	0.001%	-0.015%	-0.001%	0.001%	0.012%
Post	0.072%	0.074%	0.010%	0.001%	0.004%	-0.030%	0.001%	0.000%	0.011%
March 19									
Day	0.045%	0.038%	0.009%	0.001%	0.004%	-0.016%	0.001%	0.000%	0.008%
Morning	0.055%	0.043%	0.015%	0.001%	0.006%	-0.020%	0.001%	0.000%	0.010%
Pre	0.048%	0.045%	0.008%	0.001%	0.002%	-0.017%	0.001%	0.000%	0.007%
Post	0.035%	0.029%	0.005%	0.001%	0.003%	-0.009%	0.001%	0.000%	0.005%

Bid Price CIRF for 1,000 share Inflection Trade impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.097%	0.090%	0.019%	0.000%	0.010%	-0.036%	0.002%	0.001%	0.010%
Morning	0.112%	0.101%	0.026%	0.001%	0.006%	-0.038%	0.001%	0.002%	0.012%
Pre	0.062%	0.056%	0.006%	0.000%	0.006%	-0.010%	0.000%	0.000%	0.004%
Post	0.092%	0.091%	0.014%	0.000%	0.012%	-0.030%	0.001%	0.001%	0.005%
March 19									
Day	0.074%	0.062%	0.027%	-0.001%	0.002%	-0.029%	0.002%	0.002%	0.009%
Morning	0.091%	0.076%	0.033%	-0.001%	0.004%	-0.035%	0.001%	0.001%	0.010%
Pre	0.077%	0.064%	0.019%	0.000%	0.004%	-0.015%	0.001%	-0.001%	0.005%
Post	0.051%	0.049%	0.010%	0.000%	0.001%	-0.015%	0.001%	0.002%	0.003%

Bid Return CIRF breakdown for 1,000 share Non-Inflection Trade Impulse

Bid Price CIRF for 1,000 share Non-Inflection Trade impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.068%	-0.006%	0.083%	0.001%	0.008%	-0.031%	0.000%	0.000%	0.013%
Morning	0.082%	-0.005%	0.100%	0.001%	0.009%	-0.033%	0.001%	0.000%	0.010%
Pre	0.056%	-0.004%	0.056%	0.000%	0.007%	-0.015%	-0.001%	0.001%	0.012%
Post	0.070%	-0.006%	0.084%	0.002%	0.008%	-0.030%	0.000%	0.000%	0.013%
March 19									
Day	0.051%	-0.003%	0.055%	0.001%	0.006%	-0.018%	0.001%	0.000%	0.008%
Morning	0.069%	-0.003%	0.078%	0.001%	0.007%	-0.026%	0.001%	0.000%	0.011%
Pre	0.044%	-0.005%	0.047%	0.000%	0.008%	-0.014%	0.001%	0.000%	0.007%
Post	0.033%	-0.003%	0.035%	0.001%	0.003%	-0.008%	0.000%	0.000%	0.005%

Bid Price CIRF for 1,000 share Non-Inflection Trade impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.082%	-0.009%	0.095%	0.001%	0.014%	-0.030%	-0.001%	0.001%	0.011%
Morning	0.089%	-0.009%	0.108%	0.000%	0.009%	-0.033%	0.000%	0.002%	0.012%
Pre	0.054%	-0.004%	0.058%	0.000%	0.007%	-0.010%	-0.001%	-0.001%	0.004%
Post	0.086%	-0.007%	0.098%	0.001%	0.017%	-0.027%	-0.001%	0.001%	0.006%
March 19									
Day	0.082%	-0.006%	0.102%	0.000%	0.006%	-0.032%	0.001%	0.001%	0.011%
Morning	0.098%	-0.006%	0.122%	-0.001%	0.005%	-0.036%	0.002%	0.001%	0.011%
Pre	0.083%	-0.006%	0.096%	0.000%	0.003%	-0.017%	0.000%	0.000%	0.007%
Post	0.052%	-0.005%	0.059%	0.001%	0.007%	-0.016%	0.000%	0.001%	0.004%

Appendix 3.7: VAR Model 2 Bid Return CIRF breakdown for Change to Existing Bid and New Bid

Bid Return CIRF breakdown for 1,000 share Change to Existing Bid

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.021%	-0.001%	0.002%	0.014%	0.012%	-0.008%	0.000%	0.000%	0.002%
Morning	0.018%	0.000%	0.002%	0.007%	0.015%	-0.008%	0.000%	0.000%	0.001%
Pre	0.017%	0.000%	0.001%	0.007%	0.012%	-0.004%	0.000%	0.000%	0.001%
Post	0.022%	0.000%	0.002%	0.014%	0.012%	-0.009%	0.001%	0.000%	0.003%
March 19									
Day	0.015%	0.000%	0.001%	0.007%	0.011%	-0.005%	0.000%	0.000%	0.002%
Morning	0.022%	0.000%	0.002%	0.006%	0.019%	-0.007%	0.001%	0.000%	0.002%
Pre	0.011%	-0.001%	0.000%	0.006%	0.007%	-0.002%	0.000%	0.000%	0.001%
Post	0.010%	0.000%	0.001%	0.005%	0.006%	-0.002%	0.000%	0.000%	0.001%

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.041%	-0.003%	0.007%	0.006%	0.047%	-0.015%	-0.003%	-0.001%	0.003%
Morning	0.045%	-0.003%	0.003%	0.011%	0.051%	-0.016%	-0.002%	-0.003%	0.004%
Pre	0.024%	-0.001%	0.004%	0.004%	0.024%	-0.006%	-0.001%	-0.001%	0.001%
Post	0.030%	-0.003%	0.007%	-0.004%	0.042%	-0.011%	-0.002%	-0.001%	0.001%
March 19									
Day	0.031%	-0.003%	-0.002%	0.019%	0.037%	-0.013%	-0.005%	-0.004%	0.001%
Morning	0.035%	-0.001%	-0.004%	0.020%	0.042%	-0.015%	-0.003%	-0.005%	0.001%
Pre	0.023%	-0.003%	0.001%	0.010%	0.023%	-0.006%	-0.002%	-0.001%	0.000%
Post	0.020%	-0.003%	-0.002%	0.012%	0.024%	-0.006%	-0.003%	-0.002%	0.001%

Bid Return CIRF breakdown for 1,000 share New Bid

Bid Price CIRF for 1,000 New Bid impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.094%	-0.001%	0.002%	0.003%	0.127%	-0.042%	0.000%	0.000%	0.004%
Morning	0.114%	-0.002%	0.001%	0.002%	0.154%	-0.044%	0.000%	0.000%	0.003%
Pre	0.116%	-0.001%	0.001%	0.003%	0.143%	-0.031%	0.000%	0.000%	0.002%
Post	0.098%	-0.001%	0.001%	0.003%	0.132%	-0.041%	0.001%	0.000%	0.004%
March 19									
Day	0.086%	-0.001%	0.000%	0.002%	0.111%	-0.029%	0.000%	0.000%	0.003%
Morning	0.102%	-0.001%	0.001%	0.001%	0.134%	-0.037%	0.001%	0.000%	0.003%
Pre	0.097%	-0.001%	-0.001%	0.002%	0.122%	-0.029%	0.001%	0.000%	0.003%
Post	0.090%	-0.001%	0.000%	0.002%	0.106%	-0.019%	0.001%	0.000%	0.002%

Bid Price CIRF for 1,000 New Bid impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.148%	-0.003%	0.001%	0.001%	0.202%	-0.054%	-0.002%	-0.001%	0.005%
Morning	0.161%	-0.003%	-0.001%	0.002%	0.211%	-0.048%	-0.002%	-0.003%	0.005%
Pre	0.148%	-0.002%	0.002%	0.001%	0.175%	-0.027%	-0.001%	0.001%	-0.002%
Post	0.176%	-0.004%	0.000%	-0.002%	0.231%	-0.049%	-0.002%	0.000%	0.002%
March 19									
Day	0.123%	-0.002%	-0.001%	0.004%	0.175%	-0.049%	-0.002%	-0.003%	0.002%
Morning	0.129%	-0.003%	-0.001%	0.003%	0.184%	-0.050%	-0.002%	-0.003%	0.001%
Pre	0.169%	-0.002%	0.000%	0.002%	0.204%	-0.033%	-0.001%	-0.001%	0.001%
Post	0.142%	-0.002%	-0.003%	0.005%	0.183%	-0.039%	-0.002%	-0.003%	0.002%

Appendix 3.8: VAR Model 2 Order Flow CIRFs for Inflection and Non-Inflection Trade Impulses

Order Flow CIRFs for 1,000 share Inflection Trade

CIRFs for 1,000 Inflection Trade impulse - Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-127	255	107	37	-149	36
Morning	-121	260	80	44	-136	29
Pre	-114	229	88	-16	-178	42
Post	-119	236	121	36	-150	24
March 19						
Day	-93	204	144	42	-145	35
Morning	-97	197	122	41	-105	33
Pre	-89	194	181	40	-162	32
Post	-87	226	163	35	-188	45

CIRFs for 1,000 Inflection Trade impulse - Non-Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-115	247	46	54	-64	56
Morning	-111	216	33	38	-49	68
Pre	-83	158	31	36	-38	34
Post	-90	195	50	49	-48	34
March 19						
Day	-107	298	20	32	-75	61
Morning	-114	290	37	41	-70	66
Pre	-124	348	42	28	-48	22
Post	-72	204	-2	23	-54	42

Order Flow CIRFs for 1,000 share Non-Inflection Trade

CIRFs for 1,000 Non-Inflection Trade impulse - Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-81	470	203	62	-156	37
Morning	-75	458	187	61	-139	31
Pre	-80	338	211	29	-215	14
Post	-78	478	228	60	-161	52
March 19						
Day	-61	403	175	47	-179	35
Morning	-61	383	128	45	-145	17
Pre	-60	371	247	59	-214	42
Post	-67	409	230	38	-246	44

CIRFs for 1,000 Non-Inflection Trade impulse - Non-Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-75	388	84	81	16	44
Morning	-69	307	42	68	-24	53
Pre	-61	279	67	43	28	6
Post	-56	313	89	76	7	44
March 19						
Day	-81	337	50	42	-65	44
Morning	-67	345	6	29	-93	44
Pre	-77	210	41	25	-45	16
Post	-92	253	67	43	-31	35

Appendix 3.9: VAR Model 2 Order Flow CIRFs for Change to Existing Bid and New Bid Impulses

Order Flow CIRFs for 1,000 share Change to Existing Bid

CIRFs for 1,000 share Change to Existing Bid impulse - Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-8	56	221	83	-82	12
Morning	-4	50	242	91	-79	12
Pre	-2	52	310	80	-88	12
Post	-8	56	180	78	-105	25
March 19						
Day	-4	35	271	77	-95	13
Morning	-3	40	281	102	-67	6
Pre	-2	32	237	61	-100	20
Post	-3	37	285	63	-118	19

CIRFs for 1,000 share Change to Existing Bid impulse - Non-Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-37	138	193	267	117	-53
Morning	-39	36	141	291	75	-58
Pre	-12	114	45	159	90	-45
Post	-21	113	119	186	97	-25
March 19						
Day	-33	27	156	234	161	-106
Morning	0	-15	99	251	110	-107
Pre	-32	61	50	117	139	-77
Post	-57	32	161	137	157	-69

Order Flow CIRFs for 1,000 share New Bid

CIRFs for 1,000 share New Bid impulse - Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-27	32	401	-17	-88	40
Morning	-25	45	394	-28	-49	26
Pre	-77	30	556	-26	-199	47
Post	-20	22	401	-29	-113	48
March 19						
Day	-24	1	424	-45	-93	26
Morning	-22	1	321	-44	-53	21
Pre	-25	4	643	-67	-175	46
Post	-42	0	618	-64	-168	50

CIRFs for 1,000 share New Bid impulse - Non-Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-39	27	361	184	93	-27
Morning	-33	-2	276	169	103	-47
Pre	-35	41	358	25	128	-24
Post	-20	31	364	91	81	-11
March 19						
Day	-51	31	327	164	113	-75
Morning	-10	40	229	158	108	-89
Pre	-102	-5	305	40	75	-61
Post	-77	64	424	14	98	-41

Appendix 3.10: Robustness check of VAR Model 2

VAR Model 2b adjusts the data set from VAR Model 2 by combining the last trade in a sequence with *Inflection* trades in the VAR model. The changing observation statistics are show in Table 3.10.1.

Table 3.10.1: Average Number of Observations

	Cross-Listed Stocks			Non-Cross-Listed Stocks		
March 18	Inflection Trades	Non-Inflection Trades	Ratio of Trades	Inflection Trades	Non-Inflection Trades	Ratio of Trades
Day	3,720	4,751	1.3	812	774	1.0
Morning	1,344	1,611	1.2	319	292	0.9
Pre	647	748	1.2	169	162	1.0
Post	1,729	2,392	1.4	323	320	1.0
March 19						
Day	3,128	4,087	1.3	817	697	0.9
Morning	1,699	2,159	1.3	377	350	0.9
Pre	701	906	1.3	205	149	0.7
Post	728	1,022	1.4	235	198	0.8

The impact of removing the last trade in a sequence is illustrated by the difference in the return CIRFs in Table 3.10.2 compared to those in Table 3.12. The *Inflection* trade return CIRFs have been reduced and the *Non-Inflection* return CIRFs have increased. To cause this effect, according to the VAR model, the last trade in a sequence has less than average information content. This makes sense in terms of the calculations, as some *Inflection* trades will now sometimes have a previous trade in the same direction (i.e. the first trade in a sequence), as opposed to always being in the opposite direction. This will reduce the one period lagged covariance. At the same time, stand alone *Non-Inflection* trades (i.e. *Non-Inflection* trades preceded by only one trade in the same direction, the *Inflection* trade that starts the trend) are eliminated from the data, increasing the average number of positively correlated trades preceding a trade coded as *Non-Inflection*.

From an interpretation perspective, however, this explanation does not make sense. The market does not know if a trade is the last in a sequence until after the fact, which means the market would have already committed to its immediate reaction before knowing the trade was the last

in the sequence; the market would have to act as if it knew the trade was the final in the sequence before knowing the trade was the final in the sequence. In addition, the information content of the order presumably stems from the information available to the sender of the order, which does not change based on when the trade lands in a sequence. If the information content of an order changes with respect to its position in a sequence, it must be that the information in the order is about its order in the sequence, and not something exogenous to the trade sequence. This would correspond to the contrarian trading literature, where traders informed about liquidity are more likely to trade counter to a (uninformed) trend the longer the trend persists (Caginalp et al., 2000), further supporting the proposition that the VAR model measures liquidity instead of information.

Table 3.10.2: Return CIRFs for Active and Passive Trade Impulses

		Return CIRFs for given impulse - Cross-listed					
	Midpoint % Change	1,000 Share Inflection Trade	1,000 Share Non-Inflection Trade	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
March 18							
Day	2.133%	0.059%	0.074%	0.021%	0.094%	-0.013%	0.023%
		0.064%	0.092%	0.012%	0.021%	-0.020%	0.097%
Morning	-0.782%	0.063%	0.087%	0.018%	0.113%	-0.009%	0.019%
		0.060%	0.091%	0.008%	0.018%	-0.018%	0.103%
Pre	0.686%	0.054%	0.051%	0.016%	0.115%	-0.010%	0.016%
		0.069%	0.088%	0.009%	0.020%	-0.015%	0.111%
Post	2.244%	0.066%	0.074%	0.022%	0.099%	-0.018%	0.027%
		0.064%	0.097%	0.013%	0.021%	-0.026%	0.118%
March 19							
Day	-0.741%	0.042%	0.056%	0.015%	0.086%	-0.011%	0.018%
		0.042%	0.059%	0.008%	0.013%	-0.016%	0.089%
Morning	-0.417%	0.054%	0.075%	0.022%	0.102%	-0.011%	0.020%
		0.052%	0.087%	0.010%	0.015%	-0.021%	0.100%
Pre	0.344%	0.044%	0.048%	0.011%	0.095%	-0.011%	0.014%
		0.043%	0.048%	0.007%	0.012%	-0.015%	0.090%
Post	-0.667%	0.030%	0.041%	0.009%	0.090%	-0.008%	0.011%
		0.032%	0.045%	0.006%	0.013%	-0.010%	0.090%

	Return CIRFs for given impulse – Non-Cross-listed						
March 18	Midpoint % Change	1,000 Share Inflection Trade	1,000 Share Non-Inflection Trade	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
Day	1.319%	0.089%	0.087%	0.042%	0.147%	-0.015%	0.029%
		0.068%	0.087%	0.022%	0.025%	-0.031%	0.145%
Morning	-0.849%	0.097%	0.103%	0.048%	0.166%	-0.016%	0.031%
		0.071%	0.092%	0.024%	0.025%	-0.036%	0.169%
Pre	0.779%	0.065%	0.055%	0.025%	0.146%	0.000%	0.012%
		0.055%	0.060%	0.013%	0.015%	-0.010%	0.137%
Post	1.411%	0.089%	0.089%	0.031%	0.176%	-0.011%	0.022%
		0.070%	0.092%	0.017%	0.018%	-0.025%	0.157%
March 19							
Day	-1.713%	0.072%	0.089%	0.031%	0.123%	-0.023%	0.027%
		0.060%	0.084%	0.009%	0.017%	-0.041%	0.140%
Morning	-1.075%	0.091%	0.105%	0.036%	0.128%	-0.025%	0.030%
		0.078%	0.094%	0.005%	0.014%	-0.045%	0.151%
Pre	-0.297%	0.074%	0.076%	0.023%	0.171%	-0.013%	0.021%
		0.063%	0.092%	0.007%	0.018%	-0.037%	0.170%
Post	-0.354%	0.048%	0.052%	0.021%	0.140%	-0.009%	0.021%
		0.048%	0.061%	0.009%	0.017%	-0.025%	0.136%

Further, the last trade in the sequence contains the mean reversion trading information, as all of the trading activity, *Inflection* and *Non-Inflection*, now appears informed (in the same direction as the trade impulse) as show in Tables 3.10.3 and 3.10.4. Again, this indication of information content cannot relate to the information content of the order (liquidity seeking mean reversion trade), even if it falls naturally from the calculations.

Table 3.10.3: Bid Return CIRF breakdown for 1,000 share Inflection Trade Impulse

	Bid Price CIRF for 1,000 share Inflection Trade impulse by component - Cross-listed Stocks								
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.059%	0.069%	0.003%	0.000%	0.003%	-0.027%	0.001%	0.000%	0.010%
Morning	0.063%	0.071%	0.005%	0.000%	0.005%	-0.026%	0.000%	0.000%	0.007%
Pre	0.054%	0.057%	0.001%	-0.001%	0.002%	-0.015%	-0.001%	0.001%	0.010%
Post	0.066%	0.080%	0.001%	0.001%	0.001%	-0.027%	0.000%	0.000%	0.010%
March 19									
Day	0.042%	0.043%	0.002%	0.000%	0.004%	-0.015%	0.001%	0.000%	0.007%
Morning	0.054%	0.057%	0.002%	0.001%	0.004%	-0.019%	0.000%	0.000%	0.009%
Pre	0.044%	0.046%	0.001%	0.000%	0.006%	-0.018%	0.001%	0.000%	0.007%

Post	0.030%	0.028%	0.002%	0.000%	0.003%	-0.007%	0.000%	0.000%	0.004%

Bid Price CIRF for 1,000 share Inflection Trade impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.089%	0.100%	0.002%	0.000%	0.008%	-0.033%	0.001%	0.001%	0.010%
Morning	0.097%	0.108%	0.004%	0.000%	0.004%	-0.032%	0.001%	0.002%	0.009%
Pre	0.065%	0.064%	0.001%	0.000%	0.005%	-0.010%	0.000%	0.000%	0.004%
Post	0.089%	0.103%	0.002%	0.001%	0.009%	-0.031%	0.000%	0.000%	0.005%
March 19									
Day	0.072%	0.081%	0.008%	-0.001%	0.002%	-0.028%	0.001%	0.001%	0.008%
Morning	0.091%	0.101%	0.009%	0.000%	0.004%	-0.034%	0.000%	0.001%	0.010%
Pre	0.074%	0.075%	0.004%	0.000%	0.002%	-0.014%	0.001%	0.000%	0.005%
Post	0.048%	0.053%	0.003%	0.000%	0.002%	-0.014%	0.001%	0.001%	0.003%

Table 3.10.4: Bid Return CIRF breakdown for 1,000 share Non-Inflection Trade Impulse

Bid Price CIRF for 1,000 share Non-Inflection Trade impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.074%	0.007%	0.073%	0.002%	0.011%	-0.033%	0.000%	0.000%	0.014%
Morning	0.087%	0.006%	0.093%	0.001%	0.011%	-0.036%	0.001%	0.000%	0.010%
Pre	0.051%	0.003%	0.039%	0.001%	0.009%	-0.014%	0.001%	0.000%	0.012%
Post	0.074%	0.007%	0.068%	0.002%	0.014%	-0.032%	0.001%	0.000%	0.014%
March 19									
Day	0.056%	0.004%	0.053%	0.001%	0.007%	-0.020%	0.001%	0.000%	0.009%
Morning	0.075%	0.005%	0.076%	0.001%	0.009%	-0.028%	0.001%	-0.001%	0.012%
Pre	0.048%	0.002%	0.045%	0.001%	0.007%	-0.014%	0.001%	0.000%	0.008%
Post	0.041%	0.003%	0.036%	0.001%	0.005%	-0.010%	0.001%	0.000%	0.006%

Bid Price CIRF for 1,000 share Non-Inflection Trade impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.087%	0.010%	0.080%	0.001%	0.018%	-0.034%	-0.001%	0.001%	0.012%
Morning	0.103%	0.011%	0.096%	0.001%	0.016%	-0.037%	0.000%	0.003%	0.014%
Pre	0.055%	0.003%	0.051%	0.000%	0.010%	-0.012%	-0.001%	-0.001%	0.005%
Post	0.089%	0.010%	0.080%	0.001%	0.023%	-0.030%	-0.001%	0.001%	0.006%
March 19									
Day	0.089%	0.010%	0.094%	0.000%	0.006%	-0.035%	0.001%	0.001%	0.012%
Morning	0.105%	0.008%	0.114%	-0.001%	0.005%	-0.039%	0.003%	0.001%	0.013%
Pre	0.076%	0.009%	0.073%	0.000%	0.004%	-0.017%	0.000%	-0.001%	0.007%

Post	0.052%	0.003%	0.057%	0.001%	0.003%	-0.015%	-0.001%	0.001%	0.003%

The revised trading data set does not have a material impact on the passive order flow return CIRFs (Tables 3.10.5 and 3.10.6), or the direction of the contributions by the trading variables (although the contribution is muted compared to VAR Model 2).

Table 3.10.5: Bid Return CIRF breakdown for 1,000 share Change to Existing Bid

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.021%	0.000%	0.002%	0.014%	0.012%	-0.008%	0.000%	0.000%	0.002%
Morning	0.018%	0.000%	0.001%	0.007%	0.015%	-0.008%	0.000%	0.000%	0.001%
Pre	0.016%	0.000%	0.001%	0.006%	0.012%	-0.004%	0.000%	0.000%	0.001%
Post	0.022%	0.000%	0.002%	0.014%	0.012%	-0.009%	0.001%	0.000%	0.003%
March 19									
Day	0.015%	0.000%	0.001%	0.007%	0.011%	-0.005%	0.000%	0.000%	0.002%
Morning	0.022%	0.000%	0.002%	0.006%	0.019%	-0.007%	0.001%	-0.001%	0.002%
Pre	0.011%	0.000%	0.000%	0.005%	0.007%	-0.003%	0.000%	0.000%	0.001%
Post	0.009%	0.000%	0.000%	0.004%	0.006%	-0.002%	0.000%	0.000%	0.001%

Bid Price CIRF for 1,000 Change to Existing Bid impulse by component - Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.042%	-0.002%	0.005%	0.008%	0.048%	-0.016%	-0.003%	-0.002%	0.003%
Morning	0.048%	-0.003%	0.003%	0.011%	0.055%	-0.016%	-0.002%	-0.003%	0.004%
Pre	0.025%	0.000%	0.003%	0.004%	0.025%	-0.006%	-0.001%	-0.001%	0.001%
Post	0.031%	-0.002%	0.004%	-0.002%	0.045%	-0.012%	-0.002%	-0.001%	0.001%
March 19									
Day	0.031%	-0.005%	-0.001%	0.019%	0.037%	-0.013%	-0.005%	-0.004%	0.001%
Morning	0.036%	-0.002%	-0.002%	0.020%	0.043%	-0.016%	-0.003%	-0.005%	0.001%
Pre	0.023%	-0.002%	0.001%	0.010%	0.022%	-0.005%	-0.002%	-0.001%	0.001%
Post	0.021%	-0.003%	-0.001%	0.011%	0.023%	-0.006%	-0.003%	-0.002%	0.001%

Table 3.10.6: Bid Return CIRF breakdown for 1,000 share New Bid

Bid Price CIRF for 1,000 New Bid impulse by component – Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.094%	-0.001%	0.002%	0.004%	0.127%	-0.042%	0.000%	0.000%	0.004%
Morning	0.113%	-0.002%	0.001%	0.002%	0.154%	-0.045%	0.000%	0.000%	0.003%
Pre	0.115%	-0.002%	0.001%	0.003%	0.141%	-0.031%	0.000%	0.000%	0.003%
Post	0.099%	-0.001%	0.001%	0.003%	0.132%	-0.041%	0.001%	0.000%	0.004%
March 19									
Day	0.086%	-0.001%	0.000%	0.002%	0.112%	-0.030%	0.000%	0.000%	0.003%
Morning	0.102%	0.000%	0.000%	0.001%	0.134%	-0.037%	0.001%	0.000%	0.003%
Pre	0.095%	-0.002%	0.000%	0.002%	0.122%	-0.030%	0.001%	-0.001%	0.002%
Post	0.090%	-0.002%	0.000%	0.002%	0.106%	-0.019%	0.000%	0.000%	0.002%

Bid Price CIRF for 1,000 New Bid impulse by component – Non-Cross-listed Stocks									
March 18	CIRF	by Inflection Trade	by Non-Inflection Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.147%	-0.004%	0.000%	0.002%	0.202%	-0.055%	-0.002%	-0.001%	0.005%
Morning	0.166%	-0.003%	0.000%	0.002%	0.215%	-0.049%	-0.002%	-0.003%	0.006%
Pre	0.146%	-0.002%	-0.001%	0.001%	0.177%	-0.027%	-0.001%	0.001%	-0.002%
Post	0.176%	-0.006%	0.001%	-0.001%	0.233%	-0.051%	-0.002%	-0.001%	0.002%
March 19									
Day	0.123%	-0.003%	0.000%	0.004%	0.175%	-0.049%	-0.002%	-0.003%	0.002%
Morning	0.128%	-0.003%	-0.001%	0.003%	0.183%	-0.050%	-0.002%	-0.003%	0.001%
Pre	0.171%	-0.004%	-0.002%	0.003%	0.207%	-0.032%	-0.001%	-0.001%	0.002%
Post	0.140%	-0.003%	-0.002%	0.004%	0.181%	-0.039%	-0.002%	-0.002%	0.002%

The order flow CIRFs in Tables 3.10.7 and 3.10.8 show a marked impact from the reorganized data. Adding previously *Non-Inflection* trades to *Inflection* trades serves to more than halve the endogenous *Non-Inflection* trading volume from an *Inflection* trade; the *Inflection* trade is no longer always the first trade in a sequence. At the same time, the *Non-Inflection* trades spawn trades that are only in the same direction as the impulse – the *Inflection* trades now include a pro-trend trade that is swamping the counter-trend trades.

Table 3.10.7: Order Flow CIRFs for 1,000 share Inflection Trade

CIRFs for 1,000 Inflection Trade impulse - Cross-listed Stocks						
	Inflection	Non-Inflection	Change to Existing	New	Change to Existing	New
March 18	Trade	Trade	Bid	Bid	Ask	Ask
Day	-108	49	69	26	-109	32
Morning	-100	58	71	36	-93	27
Pre	-94	56	39	-6	-128	22
Post	-105	38	65	15	-108	31
March 19						
Day	-83	45	104	37	-111	32
Morning	-85	39	82	29	-74	23
Pre	-71	49	133	51	-130	34
Post	-77	54	138	28	-144	43

CIRFs for 1,000 Inflection Trade impulse - Non-Cross-listed Stocks						
	Inflection	Non-Inflection	Change to Existing	New	Change to Existing	New
March 18	Trade	Trade	Bid	Bid	Ask	Ask
Day	-82	56	31	46	-41	45
Morning	-89	63	26	30	-47	54
Pre	-62	39	21	31	-21	32
Post	-70	41	38	43	-32	33
March 19						
Day	-83	92	13	25	-49	52
Morning	-90	90	27	43	-45	46
Pre	-89	75	34	16	-36	28
Post	-62	67	-12	24	-55	50

Table 3.10.8: Order Flow CIRFs for 1,000 share Non-Inflection Trade

CIRFs for 1,000 Non-Inflection Trade impulse - Cross-listed Stocks						
	Inflection	Non-Inflection	Change to Existing	New	Change to Existing	New
March 18	Trade	Trade	Bid	Bid	Ask	Ask
Day	94	648	280	82	-205	40
Morning	98	621	233	70	-192	33
Pre	75	475	335	36	-297	27
Post	94	662	346	101	-216	54
March 19						
Day	83	539	232	54	-233	37
Morning	81	520	174	58	-204	27
Pre	80	493	303	54	-260	47
Post	92	544	294	48	-302	45

CIRFs for 1,000 Non-Inflection Trade impulse - Non-Cross-listed Stocks						
March 18	Inflection Trade	Non-Inflection Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	89	503	114	103	12	52
Morning	86	400	65	102	-10	67
Pre	48	379	86	56	24	1
Post	82	402	122	100	8	51
March 19						
Day	99	438	58	51	-96	52
Morning	87	465	17	28	-138	71
Pre	123	264	49	44	-72	5
Post	60	324	91	36	-20	31

Appendix 3.11: VAR Model 3 Return CIRFs for Active and Passive Trade Impulses

	Return CIRFs for given impulse - Cross-listed						
March 18	1,000 Share Greater than	1,000 Share Equal To	1,000 Share Less Than	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
Day	0.062%	0.078%	0.035%	0.017%	0.089%	-0.013%	0.022%
	0.063%	0.087%	0.035%	0.011%	0.019%	-0.020%	0.095%
Morning	0.077%	0.094%	0.037%	0.015%	0.110%	-0.009%	0.018%
	0.070%	0.097%	0.026%	0.008%	0.016%	-0.017%	0.101%
Pre	0.058%	0.066%	0.024%	0.015%	0.115%	-0.009%	0.015%
	0.066%	0.074%	0.023%	0.009%	0.019%	-0.014%	0.108%
Post	0.059%	0.083%	0.040%	0.018%	0.094%	-0.018%	0.025%
	0.061%	0.100%	0.046%	0.013%	0.018%	-0.023%	0.119%
March 19							
Day	0.048%	0.071%	0.024%	0.014%	0.085%	-0.012%	0.016%
	0.044%	0.072%	0.031%	0.008%	0.012%	-0.016%	0.088%
Morning	0.059%	0.097%	0.030%	0.021%	0.100%	-0.014%	0.018%
	0.058%	0.098%	0.046%	0.010%	0.014%	-0.022%	0.100%
Pre	0.048%	0.061%	0.024%	0.011%	0.097%	-0.010%	0.014%
	0.042%	0.068%	0.021%	0.007%	0.013%	-0.014%	0.090%
Post	0.037%	0.054%	0.020%	0.009%	0.090%	-0.008%	0.011%
	0.035%	0.059%	0.024%	0.006%	0.012%	-0.010%	0.090%

	Return CIRFs for given impulse – Non-Cross-listed						
March 18	1,000 Share Greater than	1,000 Share Equal To	1,000 Share Less Than	1,000 Share Change to Existing Bid	1,000 Share New Bid	1,000 Share Change to Existing Ask	1,000 Share New Ask
Day	0.087%	0.115%	0.056%	0.040%	0.148%	-0.015%	0.028%
	0.066%	0.120%	0.053%	0.021%	0.024%	-0.030%	0.146%
Morning	0.100%	0.133%	0.044%	0.046%	0.166%	-0.015%	0.029%
	0.077%	0.124%	0.038%	0.022%	0.024%	-0.035%	0.170%
Pre	0.059%	0.069%	0.023%	0.021%	0.147%	0.000%	0.012%
	0.053%	0.089%	0.028%	0.011%	0.013%	-0.011%	0.140%
Post	0.085%	0.116%	0.051%	0.031%	0.175%	-0.009%	0.020%
	0.069%	0.122%	0.059%	0.015%	0.016%	-0.022%	0.157%
March 19							
Day	0.073%	0.116%	0.045%	0.032%	0.123%	-0.024%	0.027%
	0.061%	0.117%	0.046%	0.009%	0.017%	-0.041%	0.139%
Morning	0.090%	0.139%	0.051%	0.035%	0.132%	-0.022%	0.026%
	0.078%	0.131%	0.049%	0.005%	0.014%	-0.039%	0.152%
Pre	0.083%	0.103%	0.028%	0.021%	0.168%	-0.013%	0.017%
	0.068%	0.122%	0.026%	0.007%	0.015%	-0.033%	0.169%
Post	0.048%	0.074%	0.016%	0.019%	0.142%	-0.009%	0.017%
	0.050%	0.076%	0.024%	0.008%	0.016%	-0.023%	0.137%

Appendix 3.12: VAR Model 3 Bid Return CIRF Breakdown for Active Trade Impulses

Bid Return CIRF breakdown for 1,000 share Greater Than Trade Impulse

Bid Price CIRF for 1,000 share Greater Than Trade impulse by component - Cross-listed Stocks

March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.062%	0.075%	0.000%	0.000%	0.001%	0.002%	-0.025%	0.001%	0.000%	0.009%
Morning	0.077%	0.096%	-0.001%	-0.001%	0.001%	0.003%	-0.027%	0.001%	0.000%	0.006%
Pre	0.058%	0.060%	0.000%	0.000%	0.000%	0.002%	-0.015%	0.001%	0.000%	0.009%
Post	0.059%	0.065%	0.000%	0.000%	0.001%	0.003%	-0.021%	0.001%	0.000%	0.012%
March 19										
Day	0.048%	0.054%	0.000%	0.000%	0.001%	0.002%	-0.017%	0.000%	0.000%	0.007%
Morning	0.059%	0.071%	0.000%	-0.001%	0.001%	0.001%	-0.022%	0.000%	0.000%	0.008%
Pre	0.048%	0.052%	0.002%	0.000%	0.000%	0.001%	-0.016%	0.001%	0.000%	0.008%
Post	0.037%	0.039%	0.000%	0.000%	0.001%	0.001%	-0.009%	0.001%	0.000%	0.005%

Bid Price CIRF for 1,000 share Greater Than Trade impulse by component – Non-Cross-listed Stocks

March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.087%	0.104%	0.001%	-0.001%	0.000%	0.003%	-0.032%	0.001%	0.001%	0.009%
Morning	0.100%	0.122%	0.001%	-0.001%	0.000%	0.002%	-0.037%	0.001%	0.001%	0.011%
Pre	0.059%	0.063%	0.000%	0.000%	0.000%	0.002%	-0.009%	0.000%	0.000%	0.003%
Post	0.085%	0.105%	0.001%	-0.001%	0.001%	0.005%	-0.030%	0.000%	0.000%	0.004%
March 19										
Day	0.073%	0.087%	0.002%	0.000%	0.000%	0.002%	-0.028%	0.001%	0.000%	0.009%
Morning	0.090%	0.108%	0.002%	0.000%	-0.001%	0.001%	-0.031%	0.001%	0.001%	0.009%
Pre	0.083%	0.092%	-0.002%	0.000%	0.001%	0.001%	-0.014%	0.000%	0.000%	0.005%
Post	0.048%	0.054%	0.000%	0.000%	0.000%	0.003%	-0.013%	0.001%	0.000%	0.003%

Bid Return CIRF breakdown for 1,000 share Equal To Trade Impulse

Bid Price CIRF for 1,000 share Equal To Trade impulse by component - Cross-listed Stocks										
March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.078%	0.002%	0.080%	0.000%	0.001%	0.011%	-0.033%	0.001%	0.001%	0.015%
Morning	0.094%	0.004%	0.099%	0.000%	0.000%	0.010%	-0.036%	0.001%	0.000%	0.014%
Pre	0.066%	0.001%	0.064%	0.000%	0.000%	0.008%	-0.018%	0.001%	0.000%	0.011%
Post	0.083%	0.002%	0.075%	0.000%	0.002%	0.016%	-0.033%	0.002%	0.000%	0.019%
March 19										
Day	0.071%	0.002%	0.073%	0.000%	0.001%	0.008%	-0.025%	0.001%	0.000%	0.012%
Morning	0.097%	0.001%	0.107%	0.000%	0.001%	0.009%	-0.037%	0.001%	0.000%	0.015%
Pre	0.061%	0.001%	0.058%	0.000%	0.001%	0.007%	-0.019%	0.001%	0.000%	0.012%
Post	0.054%	0.001%	0.052%	0.000%	0.001%	0.005%	-0.012%	0.001%	0.000%	0.007%

Bid Price CIRF for 1,000 share Equal To Trade impulse by component – Non-Cross-listed Stocks										
March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.115%	0.009%	0.105%	0.001%	0.001%	0.024%	-0.042%	0.000%	0.001%	0.016%
Morning	0.133%	0.007%	0.130%	0.000%	0.000%	0.022%	-0.046%	0.000%	0.002%	0.017%
Pre	0.069%	0.001%	0.067%	0.000%	0.001%	0.009%	-0.012%	0.000%	-0.001%	0.005%
Post	0.116%	0.007%	0.112%	0.000%	0.000%	0.022%	-0.034%	0.000%	0.001%	0.008%
March 19										
Day	0.116%	0.006%	0.129%	0.000%	-0.001%	0.011%	-0.046%	0.000%	0.001%	0.016%
Morning	0.139%	0.003%	0.157%	0.000%	0.000%	0.012%	-0.049%	0.001%	0.000%	0.016%
Pre	0.103%	0.000%	0.106%	0.000%	0.000%	0.012%	-0.022%	0.000%	0.000%	0.007%
Post	0.074%	0.006%	0.080%	0.000%	0.000%	0.005%	-0.022%	0.000%	0.000%	0.005%

Bid Return CIRF breakdown for 1,000 share Less Than Trade Impulse

Bid Price CIRF for 1,000 share Less Than Trade impulse by component - Cross-listed Stocks										
March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.035%	0.007%	0.009%	0.016%	0.001%	0.011%	-0.016%	0.001%	0.001%	0.007%
Morning	0.037%	0.007%	0.009%	0.019%	0.001%	0.011%	-0.016%	0.001%	0.001%	0.004%
Pre	0.024%	0.004%	0.004%	0.007%	0.000%	0.011%	-0.006%	0.000%	0.000%	0.004%
Post	0.040%	0.007%	0.010%	0.015%	0.002%	0.013%	-0.017%	0.001%	0.000%	0.009%
March 19										
Day	0.024%	0.006%	0.007%	0.005%	0.001%	0.009%	-0.011%	0.001%	0.000%	0.006%
Morning	0.030%	0.009%	0.018%	-0.001%	0.000%	0.011%	-0.016%	0.002%	0.000%	0.008%
Pre	0.024%	0.000%	0.004%	0.012%	0.001%	0.010%	-0.005%	0.000%	0.000%	0.002%
Post	0.020%	0.004%	0.004%	0.006%	0.001%	0.006%	-0.005%	0.001%	0.000%	0.003%

Bid Price CIRF for 1,000 share Less Than Trade impulse by component – Non-Cross-listed Stocks										
March 18	CIRF	by Greater Than Trade	by Equal To Trade	by Less Than Trade	by Change to Existing Bid	by New Bid	by Bid Price Change	by Change to Existing Ask	by New Ask	by Ask Price Change
Day	0.056%	0.017%	0.017%	0.009%	0.001%	0.027%	-0.023%	-0.002%	0.001%	0.008%
Morning	0.044%	0.016%	0.015%	0.000%	0.002%	0.024%	-0.020%	-0.001%	0.001%	0.006%
Pre	0.023%	0.011%	0.005%	-0.003%	-0.001%	0.014%	-0.005%	0.000%	0.000%	0.002%
Post	0.051%	0.014%	0.016%	0.003%	0.001%	0.034%	-0.020%	-0.001%	0.002%	0.003%
March 19										
Day	0.045%	0.012%	0.019%	0.014%	0.002%	0.010%	-0.019%	-0.001%	0.002%	0.007%
Morning	0.051%	0.011%	0.026%	0.013%	0.000%	0.014%	-0.021%	0.000%	0.001%	0.007%
Pre	0.028%	0.006%	0.005%	0.011%	0.000%	0.008%	-0.003%	-0.002%	0.001%	0.002%
Post	0.016%	0.004%	0.003%	0.004%	0.000%	0.006%	-0.005%	-0.001%	0.001%	0.002%

Appendix 3.13: VAR Model 3 Order Flow CIRFs for Active Trade Impulses

Order Flow CIRFs for 1,000 share Greater Than Trade

CIRFs for 1,000 Greater Than Trade impulse - Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	27	0	-17	127	20	-131	13
Morning	35	-3	-14	106	19	-107	4
Pre	18	-6	-25	140	19	-192	3
Post	21	3	-16	136	20	-128	15
March 19							
Day	33	3	-15	120	17	-128	18
Morning	32	1	-15	82	13	-87	11
Pre	20	13	-26	178	16	-176	17
Post	37	-3	5	192	13	-201	28

CIRFs for 1,000 Greater Than Trade impulse – Non-Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	66	12	2	24	22	-54	35
Morning	53	5	-4	14	14	-58	53
Pre	35	1	-1	33	12	-26	13
Post	56	4	2	29	23	-56	26
March 19							
Day	99	7	7	37	22	-58	19
Morning	89	25	6	21	9	-51	19
Pre	51	-11	-1	38	12	-53	-3
Post	43	-9	6	12	23	-40	4

Order Flow CIRFs for 1,000 share Equal To Trade

CIRFs for 1,000 Equal To Trade impulse - Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	42	56	52	223	93	-233	89
Morning	53	50	50	168	68	-197	61
Pre	14	30	40	202	67	-283	85
Post	37	51	44	274	128	-266	96
March 19							
Day	51	53	66	233	71	-221	74
Morning	50	62	77	167	69	-165	47
Pre	35	34	32	296	72	-234	73
Post	45	36	54	317	60	-287	98

CIRFs for 1,000 Equal To Trade impulse – Non-Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	106	89	78	122	133	25	40
Morning	57	63	55	62	140	-36	91
Pre	77	56	70	60	64	24	-16
Post	120	52	43	111	102	23	42
March 19							
Day	104	107	67	35	80	-52	81
Morning	128	87	65	26	77	-72	83
Pre	4	56	23	65	72	-39	45
Post	95	63	33	48	48	-64	64

Order Flow CIRFs for 1,000 share Less Than Trade

CIRFs for 1,000 Less Than Trade impulse - Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	127	109	479	219	82	-162	59
Morning	131	106	438	196	67	-154	50
Pre	93	72	353	212	65	-196	49
Post	140	117	531	266	101	-180	68
March 19							
Day	134	97	452	194	65	-197	52
Morning	129	110	439	154	67	-194	60
Pre	92	87	400	257	85	-191	49
Post	131	77	410	224	59	-231	43

CIRFs for 1,000 Less Than Trade impulse – Non-Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	201	155	337	155	154	70	76
Morning	139	143	292	108	157	92	50
Pre	421	103	244	82	80	46	71
Post	166	116	301	155	145	19	65
March 19							
Day	194	139	259	34	66	-63	82
Morning	192	174	274	49	91	-92	87
Pre	131	74	107	51	36	29	45
Post	90	58	204	40	37	9	23

Appendix 3.14: VAR Model 3 Order Flow CIRFs for Passive Order Impulses

Order Flow CIRFs for 1,000 share Change to Existing Bid

CIRFs for 1,000 share Change to Existing Bid impulse - Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	16	17	15	192	63	-90	19
Morning	18	15	9	216	61	-81	15
Pre	17	17	10	297	60	-95	16
Post	13	15	20	166	65	-110	29
March 19							
Day	17	9	2	271	77	-95	13
Morning	18	13	-4	278	103	-71	7
Pre	14	7	9	236	61	-102	21
Post	13	6	12	285	61	-119	18

CIRFs for 1,000 share Change to Existing Bid impulse – Non-Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	4	40	43	181	263	110	-52
Morning	-51	12	31	121	280	73	-57
Pre	80	36	42	33	141	81	-31
Post	19	25	36	90	178	92	-24
March 19							
Day	12	-9	5	158	236	164	-107
Morning	16	7	-37	71	228	84	-94
Pre	7	2	26	39	109	118	-61
Post	-6	-4	-6	137	126	137	-59

Order Flow CIRFs for 1,000 share New Bid

CIRFs for 1,000 share New Bid impulse - Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-8	1	5	371	-59	-89	44
Morning	7	1	6	369	-62	-42	30
Pre	-51	-2	5	540	-73	-198	50
Post	-12	1	9	372	-69	-113	49
March 19							
Day	-2	-13	-13	419	-47	-92	27
Morning	1	-8	-21	321	-45	-53	19
Pre	-9	-24	-5	630	-70	-171	50
Post	-25	-25	-8	607	-65	-179	48

CIRFs for 1,000 share New Bid impulse – Non-Cross-listed Stocks							
March 18	Greater Than Trade	Equal To Trade	Less Than Trade	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-38	9	21	327	171	90	-26
Morning	-43	0	20	269	158	103	-40
Pre	32	8	0	348	18	108	-15
Post	-50	-5	33	339	81	82	-14
March 19							
Day	8	-27	-10	328	165	115	-74
Morning	26	-9	-2	203	152	90	-80
Pre	-101	3	-12	296	19	35	-38
Post	9	-17	-8	385	4	77	-26

Appendix 3.15: Random and Actual Proportions of Order Size Matches

The tables show the proportion of *Greater Than*, *Equal To*, and *Less Than* trades expected if trades were matched randomly with bids and asks and the actual proportions observed in the data. For the randomly matched trades, all buy and sell trades are randomly matched with a sample of prevailing ask and bid sizes. The average of 1,000 random matching samples is computed each stock.

			Cross-Listed			
	Greater Than	Greater Than	Equal To	Equal To	Less Than	Less Than
March 18	Random	Actual	Random	Actual	Random	Actual
Day	11%	10%	10%	24%	79%	66%
Morning	12%	11%	10%	24%	78%	65%
Pre	9%	9%	8%	23%	83%	68%
Post	11%	10%	11%	25%	78%	66%
March 19						
Day	11%	11%	8%	24%	81%	65%
Morning	14%	13%	10%	28%	77%	59%
Pre	10%	10%	8%	24%	82%	66%
Post	8%	10%	6%	19%	85%	71%

			Non-Cross-Listed			
	Greater Than	Greater Than	Equal To	Equal To	Less Than	Less Than
March 18	Random	Actual	Random	Actual	Random	Actual
Day	18%	11%	12%	29%	70%	60%
Morning	18%	12%	13%	30%	69%	58%
Pre	17%	11%	12%	28%	71%	61%
Post	18%	12%	13%	28%	70%	60%
March 19						
Day	21%	13%	12%	31%	67%	55%
Morning	23%	15%	13%	34%	64%	51%
Pre	21%	13%	12%	32%	67%	54%
Post	19%	11%	11%	27%	70%	61%

Appendix 3.16: VAR Model 4 Return CIRFs for Active and Passive Order Impulses

Return CIRFs for Active and Passive Trade Impulses

	Return CIRFs for given impulse - Cross-listed									
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	0.055%	0.081%	0.030%	0.046%	0.077%	0.040%	0.017%	0.090%	-0.013%	0.021%
	0.050%	0.088%	0.030%	0.050%	0.088%	0.040%	0.010%	0.019%	-0.019%	0.096%
Morning	0.061%	0.112%	0.029%	0.068%	0.091%	0.039%	0.014%	0.112%	-0.008%	0.016%
	0.043%	0.095%	0.017%	0.070%	0.108%	0.033%	0.008%	0.016%	-0.016%	0.103%
Pre	0.033%	0.074%	0.015%	0.068%	0.064%	0.030%	0.014%	0.118%	-0.008%	0.015%
	0.052%	0.080%	0.018%	0.054%	0.076%	0.027%	0.009%	0.019%	-0.012%	0.109%
Post	0.050%	0.089%	0.036%	0.042%	0.081%	0.043%	0.019%	0.095%	-0.017%	0.024%
	0.042%	0.097%	0.040%	0.051%	0.099%	0.053%	0.012%	0.018%	-0.022%	0.118%
March 19										
Day	0.049%	0.072%	0.008%	0.035%	0.074%	0.033%	0.014%	0.085%	-0.012%	0.017%
	0.041%	0.078%	0.026%	0.033%	0.074%	0.036%	0.008%	0.012%	-0.016%	0.088%
Morning	0.059%	0.100%	0.008%	0.045%	0.101%	0.043%	0.021%	0.100%	-0.013%	0.018%
	0.057%	0.117%	0.031%	0.040%	0.099%	0.054%	0.009%	0.014%	-0.022%	0.100%
Pre	0.036%	0.077%	0.015%	0.041%	0.057%	0.027%	0.010%	0.099%	-0.010%	0.013%
	0.031%	0.080%	0.002%	0.036%	0.066%	0.026%	0.006%	0.011%	-0.014%	0.093%
Post	0.038%	0.060%	0.018%	0.031%	0.058%	0.022%	0.009%	0.090%	-0.008%	0.011%
	0.036%	0.070%	0.019%	0.027%	0.068%	0.021%	0.006%	0.013%	-0.010%	0.089%

	Return CIRFs for given impulse – Non-Cross-listed									
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	0.081%	0.133%	0.061%	0.057%	0.108%	0.045%	0.039%	0.146%	-0.014%	0.027%
	0.056%	0.115%	0.058%	0.051%	0.125%	0.049%	0.021%	0.022%	-0.028%	0.147%
Morning	0.087%	0.176%	0.063%	0.078%	0.121%	0.038%	0.038%	0.164%	-0.013%	0.025%
	0.076%	0.132%	0.021%	0.056%	0.120%	0.044%	0.018%	0.016%	-0.032%	0.168%
Pre	0.067%	0.085%	0.018%	0.022%	0.068%	0.015%	0.020%	0.154%	0.000%	0.009%
	0.019%	0.093%	0.030%	0.057%	0.085%	0.022%	0.009%	0.013%	-0.010%	0.141%
Post	0.061%	0.133%	0.054%	0.075%	0.104%	0.046%	0.030%	0.173%	-0.009%	0.017%
	0.045%	0.107%	0.067%	0.058%	0.132%	0.056%	0.014%	0.013%	-0.019%	0.156%
March 19										
Day	0.056%	0.109%	0.038%	0.070%	0.117%	0.047%	0.030%	0.126%	-0.021%	0.025%
	0.046%	0.128%	0.037%	0.055%	0.116%	0.049%	0.008%	0.017%	-0.038%	0.141%
Morning	0.075%	0.134%	0.046%	0.077%	0.150%	0.070%	0.035%	0.137%	-0.021%	0.024%
	0.061%	0.154%	0.046%	0.071%	0.128%	0.070%	0.005%	0.017%	-0.038%	0.153%
Pre	0.059%	0.116%	0.039%	0.101%	0.117%	-0.005%	0.023%	0.174%	-0.011%	0.014%
	0.059%	0.156%	0.027%	0.075%	0.145%	0.018%	0.007%	0.013%	-0.031%	0.179%
Post	0.041%	0.092%	0.013%	0.055%	0.072%	0.019%	0.016%	0.149%	-0.007%	0.016%
	0.027%	0.087%	0.025%	0.052%	0.081%	0.024%	0.005%	0.015%	-0.021%	0.146%

Appendix 3.17: VAR Model 4 Bid Return CIRF breakdown for Active Trade Impulses

Bid Return CIRF breakdown for 1,000 share Greater Than Inflection Trade Impulse

Bid Price CIRF for 1,000 share Greater Than Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.055%	0.061%	0.033%	0.050%	0.049%	0.059%	0.036%	0.038%
by Inflection Greater Than	0.071%	0.084%	0.038%	0.062%	0.054%	0.071%	0.046%	0.043%
by Inflection Equal To	-0.002%	-0.003%	-0.002%	-0.001%	-0.001%	-0.004%	-0.007%	-0.001%
by Inflection Less Than	-0.001%	-0.001%	0.000%	-0.001%	0.001%	0.001%	-0.001%	0.000%
by Non-Inflection Greater Than	0.001%	0.002%	-0.001%	0.000%	0.002%	0.002%	0.000%	0.001%
by Non-Inflection Equal To	0.000%	0.001%	0.001%	-0.001%	0.002%	0.003%	0.002%	0.001%
by Non-Inflection Less Than	0.000%	-0.001%	0.000%	0.000%	0.000%	-0.001%	0.000%	0.000%
by Change to Existing Bid	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.000%	0.001%
by New Bid	0.000%	-0.002%	0.000%	-0.001%	0.001%	-0.001%	0.001%	0.000%
by Bid Price Change	-0.021%	-0.020%	-0.010%	-0.017%	-0.016%	-0.018%	-0.009%	-0.010%
by Change to Existing Ask	0.001%	0.000%	0.000%	0.001%	0.001%	0.000%	-0.002%	0.000%
by New Ask	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.006%	0.001%	0.007%	0.007%	0.006%	0.007%	0.005%	0.005%

Bid Price CIRF for 1,000 share Greater Than Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.081%	0.087%	0.067%	0.061%	0.056%	0.075%	0.059%	0.041%
by Inflection Greater Than	0.099%	0.094%	0.070%	0.072%	0.055%	0.068%	0.054%	0.047%
by Inflection Equal To	-0.003%	-0.005%	-0.002%	-0.001%	-0.005%	-0.017%	-0.004%	-0.001%
by Inflection Less Than	-0.001%	-0.001%	0.000%	-0.001%	0.000%	0.001%	0.000%	0.000%
by Non-Inflection Greater Than	0.001%	0.010%	0.001%	0.004%	0.010%	0.030%	0.006%	0.002%
by Non-Inflection Equal To	0.001%	0.001%	0.001%	0.001%	0.005%	0.010%	-0.004%	0.001%
by Non-Inflection Less Than	0.000%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Change to Existing Bid	0.000%	0.000%	0.000%	0.001%	0.000%	0.001%	0.002%	0.000%
by New Bid	0.004%	0.006%	0.002%	0.001%	0.003%	0.002%	0.008%	-0.001%
by Bid Price Change	-0.029%	-0.025%	-0.006%	-0.020%	-0.021%	-0.025%	-0.005%	-0.008%
by Change to Existing Ask	0.001%	0.000%	0.000%	0.001%	0.002%	0.000%	0.000%	0.001%
by New Ask	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	-0.001%	0.000%
by Ask Price Change	0.008%	0.009%	0.001%	0.004%	0.006%	0.005%	0.003%	0.002%

Bid Return CIRF breakdown for 1,000 share Equal To Inflection Trade Impulse

Bid Price CIRF for 1,000 share Equal To Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.081%	0.112%	0.074%	0.089%	0.072%	0.100%	0.077%	0.060%
by Inflection Greater Than	-0.001%	0.000%	0.000%	-0.001%	-0.001%	-0.004%	-0.001%	0.000%
by Inflection Equal To	0.080%	0.113%	0.070%	0.081%	0.064%	0.089%	0.084%	0.054%
by Inflection Less Than	-0.001%	-0.001%	0.000%	-0.001%	0.000%	0.001%	0.000%	0.000%
by Non-Inflection Greater Than	0.003%	0.003%	0.001%	0.002%	0.003%	0.002%	0.003%	0.001%
by Non-Inflection Equal To	0.006%	0.005%	0.003%	0.006%	0.008%	0.020%	0.004%	0.005%
by Non-Inflection Less Than	0.001%	0.002%	0.001%	0.001%	0.001%	-0.001%	0.000%	0.000%
by Change to Existing Bid	0.001%	0.000%	0.000%	0.002%	0.001%	0.002%	0.002%	0.001%
by New Bid	0.009%	0.012%	0.006%	0.013%	0.008%	0.010%	-0.006%	0.004%
by Bid Price Change	-0.034%	-0.036%	-0.019%	-0.034%	-0.025%	-0.037%	-0.026%	-0.014%
by Change to Existing Ask	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.007%	0.000%
by New Ask	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.015%	0.012%	0.011%	0.017%	0.012%	0.017%	0.011%	0.009%

Bid Price CIRF for 1,000 share Equal To Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.133%	0.176%	0.085%	0.133%	0.109%	0.134%	0.116%	0.092%
by Inflection Greater Than	-0.007%	-0.008%	-0.002%	-0.001%	-0.004%	-0.012%	-0.009%	-0.001%
by Inflection Equal To	0.130%	0.172%	0.087%	0.135%	0.101%	0.146%	0.089%	0.103%
by Inflection Less Than	-0.002%	-0.002%	0.000%	-0.002%	-0.001%	-0.003%	0.000%	-0.001%
by Non-Inflection Greater Than	0.010%	0.009%	0.003%	0.008%	0.008%	0.008%	0.005%	0.006%
by Non-Inflection Equal To	0.011%	0.015%	0.002%	0.007%	0.018%	0.019%	0.025%	0.004%
by Non-Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.001%	0.000%	0.001%	0.000%
by Change to Existing Bid	0.001%	0.001%	0.001%	0.000%	-0.001%	0.000%	-0.002%	0.000%
by New Bid	0.020%	0.016%	0.006%	0.014%	0.008%	0.008%	0.019%	0.000%
by Bid Price Change	-0.049%	-0.047%	-0.014%	-0.038%	-0.037%	-0.047%	-0.021%	-0.024%
by Change to Existing Ask	0.001%	0.001%	0.000%	0.000%	0.001%	0.000%	0.002%	0.000%
by New Ask	0.002%	0.001%	0.000%	0.001%	0.001%	0.001%	-0.001%	0.000%
by Ask Price Change	0.017%	0.018%	0.003%	0.009%	0.014%	0.016%	0.008%	0.004%

Bid Return CIRF breakdown for 1,000 share Less Than Inflection Trade Impulse

Bid Price CIRF for 1,000 share Less Than Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.030%	0.029%	0.015%	0.036%	0.008%	0.008%	0.015%	0.018%
by Inflection Greater Than	-0.001%	-0.005%	-0.002%	0.000%	-0.001%	0.000%	-0.003%	-0.001%
by Inflection Equal To	-0.004%	-0.004%	-0.003%	-0.005%	-0.004%	-0.005%	-0.025%	-0.002%
by Inflection Less Than	0.011%	0.016%	0.000%	0.014%	-0.013%	-0.026%	0.035%	0.003%
by Non-Inflection Greater Than	0.006%	0.006%	0.004%	0.006%	0.004%	0.005%	0.001%	0.003%
by Non-Inflection Equal To	0.010%	0.009%	0.006%	0.010%	0.009%	0.020%	0.005%	0.005%
by Non-Inflection Less Than	0.004%	0.004%	0.002%	0.004%	0.003%	0.002%	0.001%	0.002%
by Change to Existing Bid	0.001%	0.001%	0.000%	0.002%	0.001%	0.001%	0.000%	0.001%
by New Bid	0.010%	0.008%	0.008%	0.010%	0.010%	0.013%	0.010%	0.009%
by Bid Price Change	-0.014%	-0.012%	-0.003%	-0.015%	-0.008%	-0.010%	0.000%	-0.005%
by Change to Existing Ask	0.001%	0.001%	0.000%	0.002%	0.001%	0.001%	-0.004%	0.001%
by New Ask	0.001%	0.001%	0.000%	0.001%	0.000%	0.000%	-0.002%	0.000%
by Ask Price Change	0.006%	0.004%	0.003%	0.008%	0.005%	0.006%	-0.002%	0.003%

Bid Price CIRF for 1,000 share Less Than Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.061%	0.063%	0.018%	0.054%	0.038%	0.046%	0.039%	0.013%
by Inflection Greater Than	-0.005%	-0.011%	-0.002%	-0.001%	-0.005%	-0.002%	0.004%	-0.006%
by Inflection Equal To	-0.013%	-0.012%	-0.007%	-0.011%	-0.012%	-0.005%	-0.007%	-0.013%
by Inflection Less Than	0.029%	0.033%	0.001%	0.026%	0.006%	0.005%	-0.003%	0.013%
by Non-Inflection Greater Than	0.018%	0.021%	0.009%	0.015%	0.011%	-0.004%	0.025%	0.004%
by Non-Inflection Equal To	0.020%	0.021%	0.007%	0.014%	0.022%	0.037%	0.025%	0.007%
by Non-Inflection Less Than	0.002%	0.003%	0.000%	0.001%	0.003%	0.003%	-0.004%	0.000%
by Change to Existing Bid	0.000%	0.001%	0.001%	0.000%	0.004%	0.006%	0.003%	0.001%
by New Bid	0.026%	0.022%	0.011%	0.027%	0.018%	0.019%	0.001%	0.010%
by Bid Price Change	-0.026%	-0.024%	-0.002%	-0.022%	-0.014%	-0.018%	-0.005%	-0.004%
by Change to Existing Ask	0.000%	0.000%	0.000%	0.000%	-0.002%	0.000%	-0.002%	-0.001%
by New Ask	0.001%	0.003%	0.000%	0.001%	0.003%	0.001%	0.001%	0.000%
by Ask Price Change	0.009%	0.007%	0.001%	0.003%	0.005%	0.006%	0.001%	0.001%

Bid Return CIRF breakdown for 1,000 share Greater Than Non-Inflection Trade Impulse

Bid Price CIRF for 1,000 share Greater Than Non-Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.046%	0.068%	0.068%	0.042%	0.035%	0.045%	0.041%	0.031%
by Inflection Greater Than	-0.002%	0.001%	0.000%	-0.003%	-0.001%	0.000%	-0.001%	-0.001%
by Inflection Equal To	-0.001%	-0.001%	0.000%	-0.001%	-0.001%	-0.001%	0.005%	-0.001%
by Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	-0.001%	-0.001%	0.000%
by Non-Inflection Greater Than	0.056%	0.077%	0.071%	0.048%	0.039%	0.053%	0.041%	0.032%
by Non-Inflection Equal To	0.001%	0.000%	0.000%	0.001%	0.002%	0.003%	0.002%	0.001%
by Non-Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Change to Existing Bid	0.001%	0.000%	0.000%	0.001%	0.000%	0.001%	0.000%	0.000%
by New Bid	0.003%	0.005%	0.002%	0.003%	0.002%	0.002%	-0.001%	0.002%
by Bid Price Change	-0.019%	-0.020%	-0.013%	-0.016%	-0.013%	-0.018%	-0.012%	-0.008%
by Change to Existing Ask	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.003%	0.000%
by New Ask	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.008%	0.007%	0.007%	0.009%	0.005%	0.006%	0.005%	0.004%

Bid Price CIRF for 1,000 share Greater Than Non-Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.057%	0.078%	0.022%	0.075%	0.070%	0.077%	0.101%	0.055%
by Inflection Greater Than	0.000%	0.001%	0.000%	0.000%	-0.001%	-0.003%	0.006%	-0.001%
by Inflection Equal To	-0.001%	-0.001%	-0.001%	-0.002%	0.000%	0.006%	0.002%	-0.001%
by Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	-0.001%	0.000%	0.000%
by Non-Inflection Greater Than	0.071%	0.096%	0.036%	0.089%	0.086%	0.086%	0.103%	0.060%
by Non-Inflection Equal To	0.002%	0.004%	-0.004%	0.002%	0.002%	0.004%	0.010%	0.001%
by Non-Inflection Less Than	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%	0.002%	0.000%
by Change to Existing Bid	0.000%	0.000%	0.000%	0.000%	-0.001%	-0.002%	-0.002%	0.001%
by New Bid	0.001%	-0.004%	-0.005%	0.004%	0.000%	0.000%	-0.007%	0.005%
by Bid Price Change	-0.023%	-0.026%	-0.006%	-0.021%	-0.024%	-0.024%	-0.018%	-0.013%
by Change to Existing Ask	0.000%	0.001%	0.000%	0.000%	0.000%	0.001%	0.001%	0.001%
by New Ask	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.007%	0.006%	0.002%	0.004%	0.008%	0.009%	0.005%	0.003%

Bid Return CIRF breakdown for 1,000 share Equal To Non-Inflection Trade Impulse

Bid Price CIRF for 1,000 share Equal To Non-Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.077%	0.091%	0.064%	0.081%	0.074%	0.101%	0.057%	0.058%
by Inflection Greater Than	-0.001%	0.000%	-0.001%	-0.001%	0.000%	-0.001%	0.001%	0.000%
by Inflection Equal To	-0.002%	-0.003%	-0.001%	-0.002%	-0.001%	-0.001%	-0.006%	-0.001%
by Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	-0.001%	-0.001%	0.000%
by Non-Inflection Greater Than	0.002%	0.007%	0.001%	0.002%	0.002%	0.002%	0.001%	0.001%
by Non-Inflection Equal To	0.078%	0.092%	0.060%	0.073%	0.078%	0.114%	0.055%	0.054%
by Non-Inflection Less Than	0.001%	0.001%	0.000%	0.001%	0.001%	0.001%	0.000%	0.001%
by Change to Existing Bid	0.001%	0.001%	0.001%	0.002%	0.001%	0.001%	0.000%	0.001%
by New Bid	0.013%	0.011%	0.010%	0.017%	0.008%	0.008%	0.013%	0.007%
by Bid Price Change	-0.033%	-0.033%	-0.016%	-0.031%	-0.027%	-0.038%	-0.015%	-0.013%
by Change to Existing Ask	0.001%	0.001%	0.001%	0.002%	0.001%	0.001%	-0.002%	0.000%
by New Ask	0.000%	0.000%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.016%	0.015%	0.011%	0.018%	0.012%	0.015%	0.009%	0.008%

Bid Price CIRF for 1,000 share Equal To Non-Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.108%	0.121%	0.068%	0.104%	0.117%	0.150%	0.117%	0.072%
by Inflection Greater Than	0.000%	-0.001%	-0.001%	0.002%	0.000%	0.000%	-0.003%	-0.001%
by Inflection Equal To	-0.003%	-0.004%	-0.001%	-0.002%	-0.002%	-0.006%	-0.002%	0.000%
by Inflection Less Than	-0.001%	-0.001%	0.000%	-0.001%	0.000%	0.000%	0.000%	-0.001%
by Non-Inflection Greater Than	0.008%	0.007%	0.000%	0.008%	0.008%	0.008%	0.005%	0.005%
by Non-Inflection Equal To	0.100%	0.122%	0.068%	0.094%	0.124%	0.169%	0.124%	0.076%
by Non-Inflection Less Than	0.001%	-0.001%	0.000%	0.000%	0.001%	0.000%	0.000%	-0.001%
by Change to Existing Bid	0.001%	0.000%	0.001%	0.001%	0.000%	-0.001%	0.000%	-0.001%
by New Bid	0.028%	0.017%	0.009%	0.025%	0.013%	0.013%	0.008%	0.006%
by Bid Price Change	-0.039%	-0.038%	-0.008%	-0.029%	-0.041%	-0.050%	-0.021%	-0.017%
by Change to Existing Ask	-0.001%	0.000%	0.000%	-0.001%	0.001%	0.001%	0.000%	0.001%
by New Ask	0.000%	0.003%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.001%
by Ask Price Change	0.016%	0.016%	0.003%	0.007%	0.014%	0.015%	0.007%	0.003%

Bid Return CIRF breakdown for 1,000 share Less Than Non-Inflection Trade Impulse

Bid Price CIRF for 1,000 share Less Than Non-Inflection Trade impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.040%	0.039%	0.030%	0.043%	0.033%	0.043%	0.027%	0.022%
by Inflection Greater Than	-0.001%	-0.001%	0.000%	-0.002%	0.000%	0.000%	-0.004%	0.000%
by Inflection Equal To	-0.003%	-0.004%	-0.003%	-0.002%	-0.002%	-0.003%	0.003%	-0.001%
by Inflection Less Than	0.000%	-0.001%	0.000%	-0.001%	0.000%	0.001%	-0.001%	0.000%
by Non-Inflection Greater Than	0.007%	0.009%	0.005%	0.007%	0.007%	0.009%	0.004%	0.004%
by Non-Inflection Equal To	0.013%	0.012%	0.006%	0.013%	0.013%	0.025%	0.007%	0.006%
by Non-Inflection Less Than	0.021%	0.022%	0.010%	0.018%	0.011%	0.011%	0.010%	0.008%
by Change to Existing Bid	0.002%	0.001%	0.001%	0.002%	0.001%	0.000%	0.001%	0.001%
by New Bid	0.012%	0.012%	0.013%	0.014%	0.009%	0.010%	0.009%	0.006%
by Bid Price Change	-0.018%	-0.017%	-0.007%	-0.017%	-0.013%	-0.020%	-0.006%	-0.006%
by Change to Existing Ask	0.000%	0.001%	0.000%	0.001%	0.001%	0.002%	0.002%	0.001%
by New Ask	0.001%	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.007%	0.005%	0.004%	0.010%	0.006%	0.008%	0.002%	0.004%

Bid Price CIRF for 1,000 share Less Than Non-Inflection Trade impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.045%	0.038%	0.015%	0.046%	0.047%	0.070%	-0.005%	0.019%
by Inflection Greater Than	-0.003%	-0.005%	0.001%	-0.001%	-0.004%	0.012%	0.004%	-0.004%
by Inflection Equal To	-0.006%	-0.011%	-0.003%	-0.005%	-0.005%	-0.018%	-0.004%	-0.004%
by Inflection Less Than	-0.002%	-0.001%	0.000%	-0.002%	0.000%	-0.002%	0.001%	0.000%
by Non-Inflection Greater Than	0.017%	0.007%	0.008%	0.014%	0.016%	0.015%	-0.012%	0.006%
by Non-Inflection Equal To	0.020%	0.024%	0.007%	0.018%	0.024%	0.044%	0.013%	0.017%
by Non-Inflection Less Than	0.003%	0.008%	-0.005%	0.003%	0.017%	0.017%	-0.015%	0.001%
by Change to Existing Bid	0.002%	0.002%	-0.001%	0.001%	0.001%	0.000%	-0.001%	0.000%
by New Bid	0.029%	0.024%	0.010%	0.033%	0.009%	0.015%	0.002%	0.005%
by Bid Price Change	-0.018%	-0.016%	-0.003%	-0.016%	-0.018%	-0.030%	0.010%	-0.004%
by Change to Existing Ask	-0.003%	-0.002%	0.000%	-0.002%	-0.001%	0.002%	-0.003%	0.000%
by New Ask	0.001%	0.001%	0.000%	0.000%	0.001%	0.004%	0.001%	0.001%
by Ask Price Change	0.007%	0.007%	0.001%	0.003%	0.008%	0.011%	0.000%	0.001%

Appendix 3.18: VAR Model 4 Bid Return CIRF Breakdown for Passive Order Impulses

Bid Return CIRF breakdown for 1,000 share Change to Existing Bid

Bid Price CIRF for 1,000 share Change to Existing Bid impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.017%	0.014%	0.014%	0.019%	0.014%	0.021%	0.010%	0.009%
by Inflection Greater Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Inflection Equal To	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Greater Than	0.001%	0.001%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Equal To	0.001%	0.001%	0.001%	0.001%	0.000%	0.001%	0.000%	0.000%
by Non-Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Change to Existing Bid	0.010%	0.005%	0.004%	0.011%	0.006%	0.005%	0.005%	0.004%
by New Bid	0.009%	0.010%	0.011%	0.009%	0.011%	0.019%	0.007%	0.006%
by Bid Price Change	-0.007%	-0.005%	-0.003%	-0.007%	-0.005%	-0.007%	-0.003%	-0.002%
by Change to Existing Ask	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
by New Ask	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.002%	0.001%	0.001%	0.003%	0.002%	0.002%	0.001%	0.001%

Bid Price CIRF for 1,000 share Change to Existing Bid impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.039%	0.038%	0.020%	0.030%	0.030%	0.035%	0.023%	0.016%
by Inflection Greater Than	-0.001%	-0.001%	0.000%	0.000%	-0.002%	0.000%	0.001%	-0.001%
by Inflection Equal To	0.000%	-0.001%	0.000%	-0.001%	-0.001%	0.001%	-0.001%	0.000%
by Inflection Less Than	0.000%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Greater Than	0.002%	0.001%	0.001%	0.002%	0.000%	-0.001%	0.002%	0.000%
by Non-Inflection Equal To	0.003%	0.000%	0.002%	0.002%	-0.003%	-0.002%	-0.004%	-0.002%
by Non-Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	-0.001%	0.000%
by Change to Existing Bid	0.005%	0.009%	0.004%	0.000%	0.017%	0.018%	0.011%	0.005%
by New Bid	0.046%	0.045%	0.017%	0.037%	0.036%	0.038%	0.022%	0.019%
by Bid Price Change	-0.015%	-0.013%	-0.004%	-0.009%	-0.012%	-0.015%	-0.005%	-0.004%
by Change to Existing Ask	-0.002%	-0.001%	0.000%	-0.001%	-0.004%	-0.002%	-0.001%	-0.001%
by New Ask	-0.001%	-0.002%	0.000%	-0.001%	-0.003%	-0.004%	0.000%	0.000%
by Ask Price Change	0.003%	0.003%	0.000%	0.001%	0.001%	0.001%	0.000%	0.000%

Bid Return CIRF breakdown for 1,000 share New Bid

Bid Price CIRF for 1,000 share New Bid impulse by component - Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.090%	0.112%	0.118%	0.095%	0.085%	0.100%	0.099%	0.090%
by Inflection Greater Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	-0.001%	0.000%
by Inflection Equal To	0.000%	-0.001%	-0.001%	0.000%	0.000%	0.000%	-0.001%	-0.001%
by Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Greater Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Equal To	0.000%	0.000%	-0.001%	0.001%	-0.001%	0.000%	-0.001%	0.000%
by Non-Inflection Less Than	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Change to Existing Bid	0.003%	0.001%	0.001%	0.002%	0.001%	0.001%	0.002%	0.002%
by New Bid	0.122%	0.148%	0.144%	0.123%	0.111%	0.132%	0.122%	0.107%
by Bid Price Change	-0.038%	-0.038%	-0.028%	-0.034%	-0.029%	-0.037%	-0.025%	-0.019%
by Change to Existing Ask	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.001%	0.000%
by New Ask	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Ask Price Change	0.004%	0.003%	0.002%	0.004%	0.003%	0.003%	0.002%	0.002%

Bid Price CIRF for 1,000 share New Bid impulse by component – Non-Cross-listed Stocks								
	March 18				March 19			
	Day	Morning	Pre	Post	Day	Morning	Pre	Post
CIRF	0.146%	0.164%	0.154%	0.173%	0.126%	0.137%	0.174%	0.149%
by Inflection Greater Than	-0.002%	-0.001%	0.000%	-0.003%	-0.001%	0.000%	0.000%	0.001%
by Inflection Equal To	0.000%	-0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.001%	0.000%
by Inflection Less Than	0.000%	0.000%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.000%
by Non-Inflection Greater Than	-0.001%	0.000%	0.000%	-0.003%	-0.001%	-0.002%	-0.001%	0.001%
by Non-Inflection Equal To	0.000%	-0.004%	0.000%	0.000%	-0.001%	0.000%	-0.004%	-0.003%
by Non-Inflection Less Than	0.000%	-0.001%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
by Change to Existing Bid	0.001%	0.002%	0.001%	0.000%	0.003%	0.002%	0.003%	0.003%
by New Bid	0.199%	0.212%	0.175%	0.220%	0.174%	0.184%	0.203%	0.180%
by Bid Price Change	-0.052%	-0.041%	-0.021%	-0.041%	-0.045%	-0.045%	-0.025%	-0.032%
by Change to Existing Ask	-0.001%	-0.001%	-0.001%	-0.001%	-0.002%	-0.001%	-0.001%	-0.001%
by New Ask	-0.001%	-0.002%	0.000%	-0.001%	-0.003%	-0.002%	0.000%	0.000%
by Ask Price Change	0.004%	0.003%	0.001%	0.002%	0.002%	0.002%	0.001%	0.001%

Appendix 3.19: VAR Model 4 Order Flow CIRFs for Active Trade Impulses

Order Flow CIRFs for 1,000 share Greater Than Inflection Trade

CIRFs for 1,000 share Greater Than Inflection Trade impulse - Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-1	-19	-38	10	3	-11	67	6	-113	8
Morning	-4	-19	-35	19	7	-2	59	-2	-120	5
Pre	-4	-25	-25	8	12	-1	66	8	-99	3
Post	-8	-13	-41	-9	-10	-21	72	6	-88	7
March 19										
Day	-2	-12	-29	18	11	-12	115	14	-115	11
Morning	-3	-20	-28	12	10	-12	81	-3	-74	0
Pre	-3	-21	-23	13	26	-16	135	2	-144	5
Post	-1	-21	-28	4	11	7	211	8	-158	24

CIRFs for 1,000 share Greater Than Inflection Trade impulse – Non-Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	17	-16	-27	29	4	1	17	19	-55	9
Morning	21	-19	-30	40	-3	5	14	25	-34	47
Pre	-23	-16	-15	21	5	-3	-7	12	-41	14
Post	15	-12	-21	40	8	-7	11	11	-29	-15
March 19										
Day	24	-32	-22	83	29	15	21	16	-70	27
Morning	17	-26	-31	105	48	9	16	13	-48	23
Pre	35	-44	-17	123	20	28	46	21	-45	-7
Post	12	-12	-11	41	3	21	-52	0	-58	23

Order Flow CIRFs for 1,000 share Equal To Inflection Trade

CIRFs for 1,000 share Equal To Inflection Trade impulse - Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-23	-24	-53	71	80	116	182	72	-229	112
Morning	-14	-20	-53	79	78	115	135	64	-201	69
Pre	-16	-19	-35	39	47	87	125	56	-278	120
Post	-22	-26	-56	60	78	102	231	103	-241	98
March 19										
Day	-14	-21	-41	72	76	95	221	72	-168	68
Morning	-30	-22	-41	57	88	112	189	73	-107	36
Pre	-9	-13	-35	59	45	68	218	67	-270	58
Post	-9	-19	-33	67	55	75	212	40	-195	97

CIRFs for 1,000 share Equal To Inflection Trade impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-133	-41	-46	139	113	118	115	111	-12	91
Morning	-174	-25	-32	127	103	72	68	92	-98	96
Pre	-25	-21	-24	113	63	96	75	42	-3	43
Post	-26	-28	-38	79	65	68	129	66	-7	80
March 19										
Day	-28	-33	-78	116	120	101	38	59	-81	110
Morning	-39	-30	-93	129	99	110	19	22	-68	109
Pre	-125	-28	-43	46	190	52	18	96	-24	52
Post	10	-5	-37	106	55	36	57	14	-69	54

Order Flow CIRFs for 1,000 share Less Than Inflection Trade

CIRFs for 1,000 share Less Than Inflection Trade impulse - Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-30	-49	-101	126	124	342	175	73	-193	54
Morning	-42	-41	-91	120	111	306	136	58	-157	38
Pre	-28	-39	-84	100	91	309	157	47	-208	41
Post	-13	-49	-90	136	126	367	213	84	-213	61
March 19										
Day	-43	-47	-81	115	104	306	181	64	-202	67
Morning	-61	-48	-77	96	116	277	195	69	-201	93
Pre	-50	-59	-72	54	105	274	247	69	-175	70
Post	-15	-34	-76	111	82	280	183	74	-200	41

CIRFs for 1,000 share Less Than Inflection Trade impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-116	-91	-99	243	207	271	105	134	-40	98
Morning	-187	-73	-83	198	214	256	105	133	29	99
Pre	4	-79	-61	230	154	223	95	78	0	34
Post	-112	-75	-82	180	151	217	90	105	-41	82
March 19										
Day	-122	-94	-115	196	198	291	116	83	-41	104
Morning	-186	-73	-88	154	239	346	118	92	-71	114
Pre	-41	-77	-115	185	146	207	46	10	18	71
Post	-92	-103	-80	128	141	206	69	21	21	19

Order Flow CIRFs for 1,000 share Greater Than Non-Inflection Trade

CIRFs for 1,000 share Greater Than Non-Inflection Trade impulse - Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-9	-10	-18	45	19	22	138	20	-112	10
Morning	3	-11	-20	45	14	20	115	24	-69	0
Pre	-6	-9	-22	26	12	15	136	18	-188	4
Post	-14	-9	-15	39	19	25	140	16	-116	13
March 19										
Day	0	-10	-13	39	13	15	101	14	-110	16
Morning	8	-9	-15	42	13	15	70	15	-78	17
Pre	-11	1	-13	23	4	15	141	3	-149	14
Post	-10	-9	-11	49	8	25	135	15	-165	19

CIRFs for 1,000 share Greater Than Non-Inflection Trade impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	8	-10	-9	80	31	34	16	11	-37	29
Morning	14	-10	-13	45	33	25	1	0	-62	33
Pre	16	-11	-8	61	6	18	50	-14	-37	-150
Post	-2	-12	-5	50	18	29	41	16	-35	11
March 19										
Day	15	-7	-17	89	11	19	23	2	-39	1
Morning	21	-5	-15	79	19	27	16	0	-42	4
Pre	-1	9	-15	37	16	7	-5	-1	-30	-13
Post	-24	-15	-12	48	13	-9	66	27	-26	-5

Order Flow CIRFs for 1,000 share Equal To Non-Inflection Trade

CIRFs for 1,000 share Equal To Non-Inflection Trade impulse - Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-12	-16	-25	64	75	82	253	106	-239	79
Morning	-10	-16	-21	70	62	71	194	75	-187	58
Pre	-12	-11	-25	31	37	64	232	77	-249	64
Post	-16	-18	-22	59	72	75	294	143	-274	88
March 19										
Day	-7	-13	-18	71	72	102	251	72	-251	79
Morning	-13	-12	-16	73	73	104	155	67	-184	50
Pre	5	-12	-17	49	39	50	309	73	-249	85
Post	-8	-14	-21	48	48	88	380	78	-332	105

CIRFs for 1,000 share Equal To Non-Inflection Trade impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-10	-19	-28	164	115	122	119	147	63	17
Morning	-9	-23	-23	117	76	91	38	120	-27	93
Pre	-59	-15	-14	148	68	87	57	66	52	-39
Post	28	-15	-19	178	73	87	118	122	53	16
March 19										
Day	-4	-19	-28	164	124	102	55	100	-51	72
Morning	2	-20	-24	214	123	115	19	96	-86	82
Pre	-32	-16	-16	51	64	40	68	65	-1	47
Post	-67	9	-68	69	73	92	29	60	-75	105

Order Flow CIRFs for 1,000 share Less Than Non-Inflection Trade

CIRFs for 1,000 share Less Than Non-Inflection Trade impulse - Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-3	-32	-49	192	164	658	252	88	-144	59
Morning	-3	-28	-45	196	153	592	215	70	-150	53
Pre	11	-29	-46	134	111	466	234	77	-187	42
Post	-3	-29	-42	189	171	701	298	103	-157	72
March 19										
Day	0	-27	-47	218	151	624	212	70	-208	50
Morning	-4	-33	-44	202	163	590	148	67	-197	44
Pre	-6	-18	-40	154	125	487	302	75	-230	42
Post	7	-23	-52	217	118	583	242	62	-244	46

CIRFs for 1,000 share Less Than Non-Inflection Trade impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-27	-41	-54	300	212	478	181	165	142	53
Morning	-50	-55	-31	186	189	372	105	169	145	29
Pre	5	-23	-39	456	141	301	56	57	73	68
Post	-8	-29	-48	251	172	407	198	155	119	51
March 19										
Day	-38	-53	-57	289	198	348	50	60	-46	71
Morning	-5	-51	-47	334	234	348	28	115	-118	106
Pre	11	-59	-63	185	123	196	39	21	23	30
Post	-102	-48	-55	136	139	262	43	38	19	28

Appendix 3.20: VAR Model 4 Order Flow CIRFs for Passive Order Impulses

Order Flow CIRFs for 1,000 share Change to Existing Bid

CIRFs for 1,000 share Change to Existing Bid impulse - Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	3	1	-5	19	16	21	194	65	-89	18
Morning	7	2	-8	18	13	19	211	58	-81	16
Pre	7	0	-4	16	16	14	293	58	-88	14
Post	1	0	-3	19	14	24	163	67	-111	28
March 19										
Day	8	1	-7	17	8	11	270	77	-96	14
Morning	8	3	-10	20	10	8	277	101	-70	7
Pre	3	0	-3	13	5	12	237	59	-102	19
Post	6	0	-5	14	7	17	276	55	-125	20

CIRFs for 1,000 share Change to Existing Bid impulse – Non-Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-9	-3	-11	33	42	52	172	252	106	-47
Morning	-2	-8	-9	-29	16	31	84	244	59	-51
Pre	12	7	-8	83	28	45	8	119	70	-31
Post	-3	-3	-6	30	36	48	88	164	89	-19
March 19										
Day	-15	-2	-8	19	-6	12	142	220	154	-102
Morning	11	7	-14	4	-1	-21	62	220	78	-87
Pre	1	-9	2	12	4	18	33	100	92	-48
Post	-27	-2	-18	0	-5	1	101	103	96	-44

Order Flow CIRFs for 1,000 share New Bid

CIRFs for 1,000 share New Bid impulse - Cross-listed Stocks

March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-12	-5	-7	0	0	0	374	-57	-90	44
Morning	-3	-4	-13	0	0	0	362	-62	-41	29
Pre	-54	-3	-6	0	0	0	505	-75	-180	48
Post	-11	-6	-3	0	0	0	370	-67	-116	51
March 19										
Day	-6	-7	-8	0	0	0	419	-46	-90	26
Morning	-2	-5	-9	0	0	0	316	-46	-55	19
Pre	-6	-10	-6	0	0	0	606	-69	-151	42
Post	-15	-17	-10	0	0	0	609	-71	-182	51

CIRFs for 1,000 share New Bid impulse – Non-Cross-listed Stocks										
March 18	Inflection Greater Than	Inflection Equal To	Inflection Less Than	Non-Inflection Greater Than	Non-Inflection Equal To	Non-Inflection Less Than	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-24	-3	-2	-13	4	24	310	157	90	-26
Morning	-8	-7	-7	-14	-6	13	236	137	97	-42
Pre	-10	-11	-7	42	9	8	220	-8	31	-4
Post	-19	-3	-3	-14	-2	30	291	56	46	-6
March 19										
Day	-10	-8	-9	26	-15	2	252	145	89	-63
Morning	22	-5	-1	19	3	0	183	149	72	-65
Pre	-28	-8	-6	-13	-2	-4	208	1	49	-27
Post	-8	4	-43	20	-14	47	348	1	58	-16

Chapter 4: Microstructure information measurement with VAR Models: Price Discovery or Price Change?

4.1: Introduction

Investment decisions that depend on market prices as inputs for asset-pricing and/or trading entry and exit points are dependent on the price discovery process. An unreliable understanding of information impounding can lead to suboptimal investment decisions and reduced performance, potentially imposing a knock-on effect on investors dependent on return outcomes. This Chapter highlights information measurement misunderstanding from the Vector Autoregression (VAR) model, extending from the results in Chapter 3. Trades that exceed the posted volume at the Best Bid or Offer (BBO) have lower price impact than trades that equal the disclosed volume and the observed price changes more closely relate to liquidity than the VAR model's measure of information. Chapter 3 finds the Cumulative Impulse Response Functions (CIRFs) for returns from trade impulses that are larger than the bid or ask volume on the passive side of the market (*Greater Than* trades) are lower than the return CIRFs for trades that are the same size as the posted volume (*Equal To* trades). This result is counter-intuitive with respect to the direct impact of the trades, which should favour the *Greater Than* trade (Easley and O'Hara, 1987). The stealth trading literature, however, suggests *Equal To* trades are more informative and should have a larger price impact (Keim and Madhavan, 1995). This Chapter provides insight to the debate by separating *Greater Than* and *Equal To* trades that do not change the prevailing BBO (*No Change* trades) into their own category, to determine if these trades cause the distinction between the price impact of the trade sizes. Importantly, my analysis suggests that *No Change* trades are responsible for a substantial amount of the trading activity induced by a trade impulse, while not contributing to the return response, calling into question the informed interpretation of trade impulses.

Chapter 3 also concludes that information impounding depends on liquidity. More liquid stocks have lower return CIRFs and experience smaller changes in their return CIRFs over successive

subperiods, while less liquid stocks have higher return CIRFs and have more larger return CIRFs across different time periods. This Chapter recasts the time issue by calculating VAR models using rolling blocks of observations over the course of a day, instead of fixed time periods. The CIRF results are then regressed against observed return metrics for subgroups defined by liquidity. The regression results point to variable information processing in the market, determined by liquidity, that partly supports the assumption that markets process information at a constant rate (Kyle, 1985) for less liquid stocks while more liquid stocks process varying amounts of information in a constant amount of time; information processing throughput is a function of liquidity. This contradicts literature that argues that information measures should react to new information, especially in certain time periods that incorporate information released while the market was closed (Amihud and Mendelson, 1987; Amihud and Mendelson, 1991), or following news releases during trading hours (Riordan et al., 2013).

For a trade that is equal to, or larger than, the posted volume to not change the BBO prices there must be undisclosed volume at the BBO that refreshes the passive order and maintains the bid or ask price prevailing before the trade. These hidden, or "iceberg", orders disclose a portion of their total volume, with the remaining volume hidden from the market until trading activity exposes the presence of undisclosed liquidity. From the point of view of the trader executing a large order, disclosing or not is a tradeoff between exposure costs, such as being undercut by better priced bids and offers, and execution costs, like not being filled on an order because the market does not know there is additional liquidity available (Buti and Rindi, 2013). The literature consistently concludes that hidden orders attract trading activity when discovered (Frey and Sandås, 2009), are routinely uncovered by market activity (De Winne and D'Hondt, 2007), and are related to increases in trading volume (Aitken et al., 2001). Compared to disclosed orders, iceberg orders are more likely to be incompletely filled, exposing the order to additional execution risk (Bessembinder et al., 2009). This Chapter finds that iceberg orders attract active trades, consistent with the literature, as *No Change* trades spawn more subsequent trading activity than trades that cause an immediate price revision.

The literature is less unified with respect to the information content of hidden order volume. One train of thought argues that open orders are better for uninformed traders, as competition between informed traders increases information revelation compared to markets which are closed (Baruch, 2005). In contrast, Zhu (2014) argues that dark pools, composed solely of hidden orders, preference uninformed traders who face lower execution costs as they disproportionately provide liquidity which is more likely to be filled in a dark pool than informed trades which cluster on the liquidity seeking side of the market. Aitken et al. (2001) finds no evidence that hidden orders are informed, supporting the supposition of Zhu (2014). Orders that react to the discovery of an iceberg order, however, appear to be informed, at least about order flow (Buti et al., 2011). The results in section 4.4 resolve the dichotomy in the literature, finding that order flow reacts as informed to the discovery of an iceberg order (i.e. when a *No Change* trade occurs), indicating it is informed about liquidity, but the price impact (return CIRFs) are the lowest of all trade types, suggesting the market does not view the *No Change* orders as being informed about price; hidden orders do not improve the information content of market prices. Interestingly, most *No Change* trades are *Equal To* in size, which are the most influential trades in Chapter 3. The finding that *Equal To* trades lose their information content when they trade against an iceberg order contributes to the literature by indicating the market has a multi-faceted process for assessing information content and we cannot rely on singular inputs to measure information. Most of the follow-on active trades reported in the order flow CIRFs are caused by *No Change* and *Less than* trade impulses. Since both trade types intend no change to the quoted BBO prices, the order flow appears to be informed about liquidity and specifically seeks to not affect price, producing the lowest price impact. Larger trades have higher price impact, but less follow-on trading activity. The lack of a trading reaction to larger trades challenges the idea that the market views them as informed about price or suggests that information about liquidity is more important than information about price to an active trader. The larger passive order flow reaction to larger trades is consistent with the information about liquidity interpretation, which completely alters the traditional paradigm of pricing information being carried by active trades. If larger trades are not considered informed, the conclusion about the importance of liquidity

remains and their price impact would be attributed to randomness. In either case, trading activity is more likely to produce estimates of order flow information than price information.

Instead of running the VAR models across static time periods, such as the morning or afternoon, I rerun the VAR models using a rolling set of data. Each day's observations are broken into blocks of observations. The first block starts at the first observation and the last block ends at the last observation, with intermediate blocks evenly distributing observations between the first and last block without overlapping. The size and number of blocks for each stock depends on the number of observations, with a minimum of 30 blocks per stock and a maximum block size of 1,000 observations. The number of blocks is the Max(# observations / 1,000, 30), with the calculated number of blocks then being used to determine the block length by finding Min(# observations / # of blocks, 1,000). For example, a stock with 15,000 observations would have 30 blocks of 500 observations (the first block would include observations 1 through 500, the second block would include observations 501 through 1,000, and so on). The return CIRFs are calculated for each of the impulses from VAR Model 1, VAR Model 2, and VAR Model 3 from Chapter 3 for each of the blocks. The return CIRFs for each impulse are regressed against the bid and ask returns on both an absolute cumulative and net basis. The "rolling" VAR models create a new line of inquiry missing from the literature: the explanatory power of the calculated return CIRFs is higher for absolute cumulative returns than for net returns, and less liquid stocks have higher absolute cumulative returns than more liquid stocks. The rolling VAR models reveal that the VAR model is measuring the amount of "work" a price must do to incorporate information (absolute cumulative or temporary return), as opposed to the amount or value of the information (permanent price change or net return). The return CIRFs are measuring the amount of back-and-forth, or the length of the path that price follows between the starting and ending prices. Higher liquidity stocks have shorter price paths (less back-and-forth) and therefore lower return CIRFs, interpreted as lower information flow, even if the permanent price change is higher. More liquid stocks are more efficient at price discovery. Changes to the amount of "work" can affect the VAR model's price impact results, and may be the reason why the presence of informed traders

reduces informed trading measures (Collin-Dufresne and Fos, 2015), if they shorten the price path to reach the permanent price change.

The remainder of this Chapter presents the data (section 4.2) used in the VAR models, followed by a discussion of the methodology (section 4.3). The *No Change* results are presented in section 4.4, starting with the *Inflection* / *Non-Inflection* / *No Change* model with *Greater Than* / *Equal To* / *No Change* results reported in section 4.4.1. The Rolling VAR model is discussed in section 4.5, with conclusions in section 4.6, followed by a discussion of further research opportunities.

4.2: Data

The data is drawn from the Toronto Stock Exchange's (TSX) historical Trades and Quotes (TAQ) for March 18 and March 19, 2009. The raw data set contains all changes at the Best Bid and Offer (BBO) including active trades and changes in the posted bid and offer quote (size and price). Odd lots (trades below 100 shares) trade exclusively in an odd lot book against each stock's registered trader and crosses executed inside the BBO, where the "active" side of the trade cannot be determined to be buy or sell, are removed. The remaining data is organized such that each trade observation, active or passive, is its own tick.

Posted bids and offers each have two types of changes, representing separate sets of observations. Changes in the existing bid and ask measure the change in the size of the prevailing bid or ask quote when there is no change in the quoted price (*Change to Existing Bid*/*Ask*). Positive observations indicate an increase in the size of the bid or ask, negative observations indicate the posted bid or ask size has decreased. The changes in existing bid/ask do not include changes caused by an iceberg order refreshing its disclosed volume, only subsequent additions and subtractions to the posted volume. Bid or ask size changes that result in a different bid or ask price are included in their own series (*New Bid*/*Ask*). For both bids and asks, the sign of the observation indicates the direction of the price change. New bids that set a higher bid price have

a positive sign, while cancelled bids that reveal a lower best bid price are signed as negative. The opposite is true for new asks, those which lower the prevailing ask price and are signed as negative, and cancelled asks, which result in a higher best ask price, are signed positively. In all cases the number of shares in the new bid or ask series represents the passive order flow, and is therefore the size of the new bid or ask that entered the market or the size of the bid or ask that was cancelled. Returns are measured separately for bid and ask prices. Every change in a bid or ask price creates a return observation, regardless of the cause of the price change (i.e. an active or a passive trade).

Active trades have two different sets of categories, each corresponding to a different VAR model. VAR Model 2 uses *Inflection*, *Non-Inflection*, and *No Change* trades, while VAR Model 3 uses *Greater Than*, *Equal To*, *Less than*, and No change trades. These active order categories are an extension of the trade categories used for the same models in Chapter 3. *No Change* trades have a volume that equals or exceeds the posted bid or ask volume against which they execute but which do not cause a change in the bid or ask price. The *No Change* trades uncover undisclosed volume, most likely in the form of an iceberg order absorbing the active trade and refreshing its disclosed volume. The *No Change* trades for both models are the same. The remaining active trade categories exclude the *No Change* trades. *Inflection* trades are in the opposite direction of the immediately preceding trade (e.g. a buy trade following a sell trade) while *Non-Inflection* trades are in the same direction as the immediately preceding trade. *Greater Than* trades are larger than the posted bid or ask volume and *Equal To* trades have the same volume as the posted BBO. In both cases, the bid or ask price will change as a result of the active trade. *Less than* trades are smaller in size than the volume on the passive side of the trade and do not directly change the bid or ask price.

The rolling VAR models use the variables from VAR Model 1, VAR Model 2, and VAR Model 3 from Chapter 3. The data is broken into blocks of observations, evenly distributed over the trading day but not overlapping. The number of ticks that each block advances from the preceding block depends on the total number of observations for each stock. Barrick Gold (ABX), for example, has

300,000 observations on March 18, 2009, which means it has 300 blocks of 1,000 observations, while Cameco (CCO) has 141,000 observations which means it has 141 blocks of 1,000 observations. Given the differences in the number of observations for each stock in the data set it is not possible for both the number of blocks and the size of the blocks to be equal. Block size is consistent across stocks to ensure the VAR model has sufficient observations to estimate meaningful coefficients. This Chapter does not estimate VAR Model 4 from Chapter 3 as the inclusion of the *No Change* category or rolling blocks of observations exacerbates the problem of some trading series having too few observations to produce reliable VAR results.

4.3: Methodology

The two models that incorporate the *No Change* trade variable are otherwise the same as the VAR models from Chapter 3 (VAR Models 2 and 3). These VAR models follow the methodology first applied by Hasbrouck (1991) and expanded by Fleming et al. (2018) and Brogaard et al. (2019). Both models incorporate passive order flow, as described in the data section, combined with two different sets of active trade variables. To avoid complications caused by simultaneous changes in the bid and ask return, there is no contemporaneous term in the models. The general form of the VAR models following the equations from Brogaard et al. (2019):

$$X_t^1 = \sum_{i=1}^{k} \beta_i^{1,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{1,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{1,y} X_{t-i}^m + u_t^1$$
$$X_t^2 = \sum_{i=1}^{k} \beta_i^{2,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{2,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{2,y} X_{t-i}^m + u_t^2$$
$$\vdots =$$
$$X_t^m = \sum_{i=1}^{k} \beta_i^{m,1} X_{t-i}^1 + \sum_{i=1}^{k} \beta_i^{m,2} X_{t-i}^2 + \cdots + \sum_{i=1}^{k} \beta_i^{m,m} X_{t-i}^m + u_t^m \qquad \textit{(eq. 4.1)}$$

where the *m* index indicates the variable, *i* is the lag, *k* is the total number of lags, which is estimated separately for each stock using Akaike Information Criterion (AIC), and *t* measures the tick (the models exist in "tick time" where each observation constitutes a tick). The set of variables used in each of the variables is shown in Table 4.1. The number of variables included in

the model limits the ability of standard diagnostic tests (F-Statistic, T-Statistics, tests of normality) to provide meaningful insight into the model results (Stock and Watson, 2001). As such, the results present the CIRF forecasts for select impulses over a 100-tick period following the impulse. As the VAR model results in this Chapter show no material change in the CIRF responses from the passive order impulses compared to Chapter 3, the results section focuses on the outcomes from the active trade impulses.

Table 4.1: VAR Model Variables

	VAR Model 2 No Change	**VAR Model 3 No Change**
X^1	Inflection Trade Ex-No-Change Trade	Greater Than Ex-No-Change Trade
X^2	Non-Inflection Trade Ex-No-Change Trade	Equal To Trade Ex-No-Change Trade
X^3	No Change Trade	Less Than Trade Ex-No-Change Trade
X^4	Change to Existing Bid	No Change Trade
X^5	New Bid	Change to Existing Bid
X^6	Bid Price Change	New Bid
X^7	Change to Existing Ask	Bid Price Change
X^8	New Ask	Change to Existing Ask
X^9	Ask Price Change	New Ask
X^{10}		Ask Price Change

Each day is separated into different time subperiods, covering the Morning (9:30am to 11:59.59am), Pre (noon to 2:15pm), and Post 2:15pm time periods. The 2:15pm distinction delineates pre- and post-FOMC announcement time periods in the March 18, 2009 data, which is replicated for March 19th for comparison purposes. The stocks are separated into four subgroups (as in Chapter 3), which are based on the amount of active trading activity (Group 1 has the most trading activity, Group 4 the least). Given Chapter 3 highlights the distinct differences in the results between these subgroups, these groups are further explored in this Chapter.

In contrast to Chapter 3 where the VAR Models split the trading day into subperiods, with some of the subgroups showing return CIRF differences between subperiods (the less liquid subgroups) while other subgroups did not (the more liquid subgroups), here, instead of discrete time periods, the Rolling VAR Model uses blocks of observations, that roll across each day's data. Each

observation block has return CIRFs calculated for each order impulse, the net and absolute cumulative returns for both bid and ask prices, and the midpoint price change. Net returns are the product of the bid/ask returns over the observation block while the absolute cumulative return is the product of the absolute bid/ask returns. Net returns approximate the midpoint return ("as the crow flies"), but the absolute cumulative returns can vary significantly ("driving distance"). The return measures (net, absolute cumulative, and midpoint) are each regressed against the return CIRF results for each impulse across the blocks, to measure how much of the change in the returns between blocks is explained by the changes in the return CIRFs. Blocks with outlier CIRF results, defined as 15 or more standard deviations from the mean, are removed from the regression. Regression performance is measured by the R^2 from a simple linear regression with the return measure as the dependent variable and the return CIRF as the independent variable:

$$Return\ Measure_t = Intercept + b_1 Return\ CIRF_t + \varepsilon_t \qquad \textit{(eq 4.2)}$$

where Return Measure is one of Midpoint Price Change, Net Return, or Absolute Cumulative Return, and Return CIRF is the return CIRF of VAR Model 1, 2, 3, or 4 for a selected order flow impulse. The R^2 results then become inputs for cross-sectional summary statistics and correlations for all stocks and the four subgroups used in the *No Change* VAR models.

4.4: VAR Model 2 *No Change* Results

To start, I discuss the results for the VAR models that include *No Change* trades and divide the data into distinct subperiods (the rolling VAR model results are presented in section 4.5). Average trade size and number of observations for the VAR Model 2 dataset that splits active trades between *Inflection* (*Ex-No-Change*), *Non-Inflection* (*Ex-No-Change*), and *No Change* trades is shown in Table 4.2, separated into subgroups 1 (most liquid) through 4 (least liquid). For all subgroups and subperiods, the *No Change* trades are larger than both *Inflection* and *Non-Inflection* trades. The Difference columns show the change in the *Inflection* and *Non-Inflection*

trade sizes between Chapter 3 and the *Ex-No-Change* variables in this Chapter. In line with expectations, *No Change* trades are larger than *Ex-No-Change* trades, since they comprise the *Greater Than* and *Equal To* trade categories. The variability of the size of the *No Change* trades relative to the size of the bid and ask increases as liquidity falls across the subgroups suggesting that liquidity driven trading decisions increase in importance and becomes more aggressively sized to available liquidity when liquidity is lower and execution costs are higher (Table 4.3 reports the size of the *No Change* trades as a percent of the time weighted bid and ask size for each subgroup, time weighted bid and ask sizes are reported in Appendix 4.1). The average number of *No Change* trades comprise a small portion of the average number of active trade observations for all subgroups (for example, there are 516 *No Change* trades in Group 1 for the full day on March 18, but 5,594 and 15,188 *Inflection* and *Non-Inflection* trades for the same time period, respectively) but are a larger portion for Groups 3 and 4 (~4.5%) than Groups 1 and 2 (~2.5%). For all subgroups, most of the *No Change* trades were previously included in the *Non-Inflection* category which reinforces the idea that they are liquidity seeking and follow in the same direction of trades that uncover hidden liquidity.

Table 4.2: Average Trade Size and Number of Observations for Active Trades

This table reports the number and size of trade variable observations use in the No Change version of VAR Model 2 for each subgroup of stocks, broken down by subperiod. Each panel presents results for a specific stock group, with the first 5 columns containing trade size information and columns 6 to 10 reporting information about the number of trade observations. Columns 1 to 3 in each panel report the average size of *Inflection Ex-No-Change* trades (*Inflection* trades that are not also *No Change* trades), *Non-Inflection Ex-No-Change* trades (*Non-Inflection* trades that are no also *No Change* trades), and *No-Change* trades for each stock group. For example, for the day subperiod on March 18th, the average size of *Inflection Ex-No-Change* trades for Group 1 stocks is 561 shares. Column 4 presents the size difference between average *Inflection Ex-No-Change* trades and average *Inflection* with *No Change* trades. For example, for the day subperiod on March 18th for Group 1 stocks the difference is -10, meaning average *Inflection Ex-No-Change* trades are 10 shares smaller than *Inflection* trades that include *No Change* trades. Column 5 repeats the analysis from column 4 for *Non-Inflection* trades. Columns 6 through 8 present the average number of *Inflection Ex-No-Change*, *Non-Inflection Ex-No-Change*, and *No Change* trades in each subgroup, respectively. For example, in the day subperiod of March 18th for Group 1 stocks, there are an average of 5,594 *Inflection Ex-No-Change* trades per stock. Column 9 presents the differences in the average number of *Inflection Ex-No-Change* trades and *Inflection* trades that include *No Change* trades. For example, for the day subperiod of March 18th for Group 1 stocks, the difference is -58, meaning the average number of *Inflection Ex-No-Change* trades is 58 less than the average number of *Inflection* with *No Change* trades. Column 10 repeats the column 9 analysis for *Non-Inflection* trades.

	Group 1 - Average Trade Size					Group 1 - Average # Observations				
	No Change Model			Difference		No Change Model			Difference	
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection
Day	561	380	919	-10	-14	5,594	15,188	516	-58	-459
Morning	545	399	947	-10	-18	1,998	5,028	222	-24	-199
Pre	560	431	983	-17	-16	881	2,089	86	-12	-74
Post	559	354	869	-7	-10	2,715	8,071	208	-22	-186
Mar 19										
Day	563	382	917	-15	-18	4,565	12,785	592	-56	-536
Morning	554	381	906	-12	-18	2,719	7,610	341	-32	-309
Pre	569	380	923	-17	-17	925	2,570	113	-13	-100
Post	576	397	940	-19	-19	921	2,605	138	-12	-127

	Group 2 - Average Trade Size					Group 2 - Average # Observations				
	No Change Model			Difference		No Change Model			Difference	
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection
Day	370	300	719	-10	-13	2,601	6,344	240	-31	-210
Morning	396	325	679	-10	-11	977	2,235	96	-14	-82
Pre	371	299	847	-10	-15	459	1,109	39	-5	-34
Post	345	282	716	-9	-13	1,165	3,000	105	-11	-94
Mar 19										
Day	430	317	800	-17	-17	2,230	5,446	230	-32	-197
Morning	443	323	770	-15	-16	1,177	2,711	115	-18	-97
Pre	414	304	825	-29	-21	511	1,290	56	-8	-48
Post	417	323	957	-13	-16	542	1,446	59	-7	-52

	Group 3 - Average Trade Size					Group 3 - Average # Observations				
	No Change Model			Difference		No Change Model			Difference	
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection
Day	316	273	703	-13	-24	1,156	2,554	167	-30	-137
Morning	327	278	538	-10	-14	443	941	70	-12	-58
Pre	327	287	867	-25	-28	221	462	26	-5	-20
Post	299	260	741	-12	-32	491	1,150	71	-13	-58
Mar 19										
Day	363	307	659	-17	-23	1,084	2,409	214	-40	-175
Morning	363	317	657	-12	-28	493	1,087	95	-16	-79
Pre	340	299	655	-21	-18	288	583	54	-11	-43
Post	386	298	700	-22	-18	303	739	65	-12	-53

	Group 4 - Average Trade Size					Group 4 - Average # Observations				
	No Change Model			Difference		No Change Model			Difference	
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection	Non-Inflection
Day	453	399	965	-16	-23	438	940	67	-3	-36
Morning	452	398	1041	-8	-20	152	333	25	-1	-15
Pre	461	414	878	4	-9	97	202	16	-1	-9
Post	464	422	1006	-19	-16	191	411	28	2	-5
Mar 19										
Day	455	407	1238	-30	-33	394	796	58	-12	-46
Morning	503	446	1188	-16	-27	184	384	32	1	-11
Pre	404	380	1337	-1	-9	102	186	12	-1	-6
Post	465	399	2059	-29	-22	118	245	17	-2	-10

Table 4.3: Average *No Change* Trade Size as Percent of Time Weighted Bid and Ask Sizes

The table below presents the average size of *No Change* trades as a percentage of the time weighted bid and ask size prevailing at the time the *No Change* trade occurred, for each subperiod. Group data is presented in pairs of columns, with the first column reporting the average size of *No Change* trades in each subperiod as a percent of the time weighted bid size in the same subperiod and the second column presenting the average size of *No Change* trades in each subperiod as a percent of the time weighted ask size in the same subperiod. For example, the average *No Change* trade size in the day subperiod of March 18th for Group 1 stocks is 34.7% of the time weighted bid size and 31.4% of the time weighted ask size in the same subperiod (columns 1 and 2, respectively).

	Group 1		Group 2		Group 3		Group 4	
March 18	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size
Day	34.7%	31.4%	42.1%	41.8%	98.9%	93.5%	46.7%	44.6%
Morning	40.5%	35.5%	43.2%	47.5%	84.9%	74.9%	50.5%	49.3%
Pre	35.4%	32.9%	42.2%	42.3%	109.5%	102.5%	37.3%	38.6%
Post	29.8%	27.2%	47.4%	40.3%	103.4%	109.3%	58.8%	47.8%
March 19								
Day	31.3%	26.9%	42.3%	39.9%	84.8%	85.2%	54.3%	55.5%
Morning	33.5%	31.3%	47.5%	41.8%	88.4%	105.0%	61.2%	63.2%
Pre	32.8%	27.1%	43.3%	41.9%	82.7%	86.3%	62.6%	59.3%
Post	27.7%	22.5%	42.3%	42.0%	86.6%	69.7%	69.9%	76.3%

The bid price return CIRFs for each of the active trading impulses is presented in Table 4.4. Noticeably, and perhaps as expected, the *No Change* trade impulse has lower price impact than the other active trade categories by an order of magnitude in most cases. The difference in return CIRFs is further exacerbated by the price impact being per trade impulse and the *No Change* trades account for less than 5% of the trading activity (i.e. trade impulses). From Chapters 2 and 3, the bulk of the active trade return CIRFs are attributable directly to the trade impulse, as opposed to follow-on trading/passive order activity, and the *No Change* trades explicitly remove the direct impact of the initial trade impulse (i.e. the *No Change* trade impulse does not change the BBO prices); all of the *No Change* trade's price impact must be in the subsequent market reaction. From a price impact perspective, the market does not appear to interpret the *No Change* trade as informed. Since hidden liquidity can only be uncovered by the *No Change* trade, the first trade that encounters the hidden liquidity does so without knowing that there is more passive volume than was disclosed. As such, the information content of that first order, when entered, could not have incorporated any information content related to the hidden liquidity (the first order is part of the *No Change* data). The market, however, can factor the revealed hidden liquidity into its interpretation of the information content of subsequent orders. Orders that are triggered by the discovery of hidden liquidity and show up in the trade CIRFs in Table 4.6, appear

to be liquidity seeking as opposed to price revealing since they have minimal price impact (the *No Change* columns in Table 4.4). The lower return CIRFs of the *No Change* trades, despite the order flow CIRFs, suggest the VAR model is measuring information about order flow, as per O'Hara (2015), rather than information about value.

Table 4.4: Average Bid Return CIRFs for Active Trade Impulses

The following table reports the average bid return CIRFs caused by the trade impulses in the column header, segmented by subperiod and subgroup. Group 1, Group 2, Group 3, and Group 4 results are presented in columns 1 to 3, 4 to 6, 7 to 9, and 10 to 12 respectively. In each 3 column set of subgroup results, the first column reports the average bid return CIRFs for an *Inflection Ex-No-Change* impulse, the second column reports the average bid return CIRFs for a *Non-Inflection Ex-No-Change* impulse, and the third column reports the average bid return CIRFs for a *No Change* impulse. For example, for the day subperiod of March 18th for Group 1 stocks, the average bid return CIRF resulting from an *Inflection Ex-No-Change* impulse is 0.015%; the *Non-Inflection Ex-No-Change* impulse causes an average 0.020% bid return CIRF for the same subgroup in the same subperiod. For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Average Bid Return CIRFs for Active Trade Impulses

	Group 1			Group 2		
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change
Day	0.015%	0.020%	0.003%	0.040%	0.047%	0.008%
	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.018%	0.023%	0.002%	0.039%	0.046%	0.008%
	0.0	0.0	0.01	0.0	0.0	0.01
Pre	0.016%	0.018%	0.004%	0.032%	0.038%	0.034%
	0.0	0.0	0.02	0.0	0.0	0.18
Post	0.014%	0.020%	0.003%	0.047%	0.052%	0.009%
	0.0	0.0	0.01	0.0	0.0	0.0
Mar 19						
Day	0.012%	0.018%	0.002%	0.031%	0.039%	0.005%
	0.0	0.0	0.02	0.0	0.0	0.0
Morning	0.014%	0.020%	0.003%	0.035%	0.044%	0.009%
	0.0	0.0	0.01	0.0	0.0	0.11
Pre	0.012%	0.017%	0.005%	0.027%	0.036%	0.012%
	0.0	0.0	0.09	0.0	0.0	0.08
Post	0.010%	0.014%	0.004%	0.028%	0.032%	0.022%
	0.0	0.0	0.12	0.0	0.0	0.15

Average Bid Return CIRFs for Active Trade Impulses

	Group 3			Group 4		
Mar 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change
Day	0.059%	0.064%	0.009%	0.114%	0.105%	0.015%
	0.0	0.0	0.07	0.0	0.0	0.01
Morning	0.068%	0.074%	0.012%	0.122%	0.127%	0.023%
	0.0	0.0	0.04	0.0	0.0	0.05

Pre	0.040%	0.046%	0.018%	0.076%	0.072%	0.012%
	0.0	0.0	0.07	0.0	0.0	0.17
Post	0.057%	0.063%	0.008%	0.105%	0.101%	0.035%
	0.0	0.0	0.26	0.0	0.0	0.0
Mar 19						
Day	0.048%	0.059%	0.009%	0.090%	0.103%	0.013%
	0.0	0.0	0.13	0.0	0.0	0.14
Morning	0.059%	0.069%	0.016%	0.089%	0.112%	0.011%
	0.0	0.0	0.15	0.0	0.0	0.33
Pre	0.048%	0.050%	0.002%	0.092%	0.087%	0.008%
	0.0	0.0	0.67	0.0	0.0	0.32
Post	0.036%	0.038%	0.005%	0.060%	0.059%	0.018%
	0.0	0.0	0.09	0.0	0.0	0.0

The reaction of the bid price CIRFs for *Inflection* and *Non-Inflection* trades are different for each subgroup. Table 4.5 shows the change of the bid return CIRFs for the VAR Models that include a *No Change* trade variable from the bid return CIRFs for VAR Model 2 from Chapter 3. The impact on *Inflection* and *Non-Inflection* return CIRFs from removing *No Change* trades rises as liquidity falls, points to the influence of liquidity on information measurement. The reversal of the sign of the change in Group 4, the least liquid of the groups, reinforces the point that liquidity matters for information impounding. Although the absolute size of the changes are small in comparison to the return CIRFs, the changes are caused by relatively smaller changes in the number of trades. For example, the Group 3 *Non-Inflection* Change for the day on March 18 is 0.011% compared to the corresponding return CIRF of 0.064% (a change of 16.7%), but this change is caused by removing 167 *No Change* trades 3,877 total trades (a change of 4.3%). *No Change* trades have a disproportionate impact on the return CIRF results. This is intuitive as the *No Change* return CIRFs are lower than the *Ex-No-Change* trade categories. Group 4, however, shows some negative changes to the return CIRFs when there is a *No Change* trade variable. The average return CIRF for *No Change* trades in Group 4 in the negative change cases must be larger than *Inflection* and *Non-Inflection* trades, opposite to the observed results in Groups 1 to 3. Since Group 4 has the lowest liquidity, the *No Change* trades may signal that VAR is measuring the market's reaction to information about liquidity, but the lower liquidity levels in Group 4 mean the reaction to discovering hidden liquidity is more aggressive and may be more likely to fill the hidden liquidity and move the price than in the other subgroups. Alternatively, the liquidity in the *Ex-No-Change* categories is lower than the *No Change* category, and if traders do not trade if they do not believe they will fill enough of their order, typical disclosed liquidity inhibits trading. The higher liquidity

on the passive side of the *No Change* trades attracts additional active trades (Biais et al., 1995) and the increasing probability of being filled causes the passive order to reprice (Cohen et al., 1981).

Table 4.5: Average Bid Return CIRF changes by subgroup

This table reports the difference in average bid returns CIRFs between *Inflection Ex-No-Change* and *Non-Inflection Ex-No-Change* trade variables and *Inflection* and *Non-Inflection* trade variables that include *No Change* trades. Results are presented for each subperiod, with pairs of columns containing data for each subgroup of stocks. The first column in each pair of columns presents the differences in the average bid return CIRFs between *Inflection Ex-No-Change* and *Inflection* trades that include *No Change* trades, with the second column repeating the calculation for the difference in average bid return CIRFs between *Non-Inflection Ex-No-Change* and *Inflection* trades that include *No Change* trades. For example, for the day subperiod of March 18th for Group 1 stocks, the difference between *Inflection Ex-No-Change* average bid return CIRFs and *Inflection* average bid return CIRFs is 0.000%; the same subgroup and subperiod has a difference of 0.001% for the difference in average bid return CIRFs between *Non-Inflection Ex-No-Change* and *Non-Inflection* trade variables, meaning the average bid return CIRF caused by *Non-Inflection Ex-No-Change* trades is 0.001% higher than the average bid return CIRF caused by *Inflection* trades that include *No Change* trades.

Average Bid Return CIRF changes by subgroup								
	Group 1		Group 2		Group 3		Group 4	
March 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	Inflection Ex-No-Change	Non-Inflection Ex-No-Change
Day	0.000%	0.001%	0.001%	0.003%	0.005%	0.011%	0.003%	0.003%
Morning	0.001%	0.002%	0.002%	0.003%	0.006%	0.009%	-0.001%	0.006%
Pre	0.000%	0.001%	0.001%	0.002%	0.003%	0.005%	-0.004%	-0.002%
Post	0.000%	0.001%	0.001%	0.003%	0.003%	0.009%	-0.010%	-0.005%
March 19								
Day	0.001%	0.002%	0.001%	0.003%	0.005%	0.009%	0.009%	0.015%
Morning	0.001%	0.002%	0.001%	0.003%	0.002%	0.009%	-0.012%	-0.003%
Pre	0.001%	0.001%	0.001%	0.002%	0.006%	0.006%	0.003%	0.003%
Post	0.001%	0.001%	0.001%	0.002%	0.003%	0.003%	0.005%	0.006%

Part of the answer to the return CIRFs of the *No Change* trades is explained by the order flow CIRFs for a *No Change* trade impulse (Table 4.6). The order flow CIRFs for *Inflection* and *Non-Inflection* trade impulses are not reported in Table 4.6, but they have lower active trade CIRFs and higher passive order flow CIRFs than the order flow CIRFs for VAR Model 2 in Chapter 3 (see Appendix 4.2). Therefore, the *No Change* trade impulse in Table 4.6 produce larger active order flow CIRFs, and smaller passive order flow CIRFs. Although the market reaction in terms of price is lowest for *No Change* trade impulses, the market reaction in terms of follow-on trading activity is highest. As soon as the *No Change* trade executes the market becomes aware that there is hidden volume. Subsequent trades attempt to access the hidden liquidity, with some of these

trades not filling the undisclosed volume (follow-on *No Change* trades) and others completing the iceberg order (follow-on *Non-Inflection* trades). If the market perceived *No Change* trades as other *Inflection* or *Non-Inflection* trades, there should not be any observed difference in order flow CIRFs. In comparison, *Inflection* and *Non-Inflection* trade impulses spawn *No Change* CIRFs that are single digit or below 50 shares, respectively, suggesting the *No Change* order flow spawned by a *No Change* trade impulse is specific to the *No Change* trade impulse (follow-on trading activity accessing the now uncovered liquidity) and not the result of trades randomly encountering hidden liquidity.

The passive order flow CIRFs for the *No Change* trade impulse are opposite to the *Inflection* and *Non-Inflection* trade impulses, which are consistently positive for changes in the existing bid and negative for change in the existing ask (i.e. prices react as though the *Inflection* and *Non-Inflection* trades are informed). The *No Change* trade impulse is more likely to draw in additional passive order flow volume, which is a signal the market is not anticipating a price change (i.e. passive orders do not "get out of the way"). The order flow CIRFs suggest that liquidity begets liquidity, and with respect to order flow CIRFs, the VAR model is measuring the information the market has about order flow. This is reinforced by the increasingly positive reaction of the passive order flow CIRFs between Groups 1 and 4 (decreasing in liquidity).

Table 4.6: Average Order Flow CIRFs for No Change trade impulse

The table below presents the average order flow CIRFs for a *No Change* trade impulse in each subperiod, with subgroup results presented in separate panels. The column headers indicate the specific order flow CIRF being presented in that column. For example, for the day subperiod of March 18th, a *No Change* trade impulse induces an average order flow response of -69 shares (i.e. sell of 69 shares) for *Inflection Ex-No-Change* trades (column 1 in the first panel) and 301 shares for *Non-Inflection Ex-No-Change* trades (column 2 in the first panel). For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

	Group 1						
	Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse						
March 18	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-69	301	202	38	15	52	8
	0.0	0.0	0.0	0.27	0.07	0.13	0.01
Morning	-76	300	228	-7	11	109	9
	0.01	0.0	0.0	0.88	0.24	0.04	0.09

Pre	-77	282	180	146	22	167	13
	0.01	0.0	0.0	0.05	0.01	0.05	0.17
Post	-63	297	184	39	16	-16	8
	0.0	0.0	0.0	0.56	0.09	0.66	0.08
March 19							
Day	-48	223	182	-40	-2	-29	4
	0.0	0.0	0.0	0.11	0.80	0.51	0.55
Morning	-58	259	179	-32	-12	-21	0
	0.02	0.0	0.0	0.20	0.42	0.53	0.99
Pre	-41	245	119	36	3	-180	6
	0.01	0.01	0.0	0.66	0.33	0.18	0.46
Post	-78	139	194	-103	7	98	12
	0.03	0.01	0.0	0.15	0.39	0.44	0.08

Group 2

Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse

	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
March 18							
Day	-77	473	316	12	26	38	15
	0.0	0.0	0.0	0.59	0.01	0.34	0.04
Morning	-86	414	284	41	17	29	2
	0.0	0.0	0.0	0.18	0.30	0.61	0.89
Pre	-79	387	129	233	20	-143	96
	0.0	0.0	0.0	0.05	0.03	0.17	0.12
Post	-64	569	342	-18	42	67	16
	0.0	0.0	0.0	0.77	0.0	0.28	0.06
March 19							
Day	-65	417	203	-32	9	16	10
	0.0	0.0	0.0	0.59	0.35	0.57	0.19
Morning	-78	405	203	-85	8	59	9
	0.0	0.0	0.0	0.11	0.65	0.41	0.52
Pre	-80	483	230	-25	8	-303	55
	0.01	0.0	0.0	0.70	0.72	0.14	0.01
Post	-54	683	173	59	74	-327	10
	0.13	0.01	0.0	0.53	0.09	0.18	0.23

Group 3

Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse

	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
March 18							
Day	-111	435	385	117	18	49	12
	0.0	0.0	0.0	0.24	0.30	0.13	0.62
Morning	-110	453	271	60	27	64	36
	0.03	0.0	0.0	0.47	0.38	0.07	0.30
Pre	-40	518	203	-22	149	34	21
	0.0	0.01	0.0	0.72	0.29	0.43	0.23
Post	-86	426	326	191	22	-18	-4
	0.01	0.0	0.0	0.36	0.49	0.73	0.88
March 19							
Day	-74	364	225	70	42	-46	23
	0.0	0.0	0.0	0.32	0.02	0.36	0.20
Morning	-134	498	337	9	56	-87	8
	0.03	0.01	0.0	0.76	0.16	0.21	0.47
Pre	-64	118	167	202	38	15	37
	0.04	0.13	0.0	0.22	0.23	0.83	0.19
Post	-105	273	130	36	57	33	7
	0.01	0.0	0.0	0.27	0.04	0.41	0.82

	Group 4						
	Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
March 18							
Day	-79	349	231	46	55	155	-16
	0.0	0.0	0.0	0.13	0.0	0.0	0.39
Morning	-82	349	156	24	67	105	-10
	0.0	0.0	0.0	0.54	0.04	0.01	0.67
Pre	-91	391	169	65	66	71	-8
	0.0	0.0	0.0	0.27	0.05	0.38	0.79
Post	-60	359	173	88	79	293	55
	0.0	0.0	0.0	0.01	0.0	0.02	0.51
March 19							
Day	-91	300	216	-33	37	-44	25
	0.0	0.0	0.0	0.29	0.05	0.46	0.19
Morning	-171	373	215	-5	29	1	18
	0.0	0.0	0.0	0.92	0.11	0.99	0.33
Pre	-132	170	55	-25	58	148	-9
	0.01	0.02	0.0	0.79	0.04	0.02	0.64
Post	-63	347	156	2	80	13	1
	0.02	0.0	0.0	0.95	0.01	0.87	0.96

Adding the *No Change* trade category to VAR Model 2 from Chapter 3 creates results that are consistent with the VAR model being a measure of liquidity instead of information. The returns CIRFs for the *Inflection* and *Non-Inflection* trades (both *Ex-No-Change* trades) increase at the same time that the liquidity on the passive side of these trades declines. The *No Change* trades that target liquidity have the smallest return CIRFs but the highest order flow CIRFs, indicating the market increases its trading activity when liquidity increases, even though there is less price movement – the market is looking for liquidity not subsequent price changes.

4.4.1: VAR Model 3 *No Change* Results

The average trade size and number of observations for the active trade categories in VAR Model 3 are reported in Table 4.7. Separating *No Change* trades from the other active trade categories reveals a different set of changes than the VAR Model 2 trade categories. For the more liquid subgroups (1 and 2) the *No Change* trades are smaller than the average *Greater Than* and *Equal To* trade (the Differences columns are largely positive), but are larger than average in the less liquid subgroups (the Differences columns are largely negative). Aside from Group 1, most of the *No Change* trades are *Equal To* rather than *Greater Than*. The non-random sizing of the *Equal To*

trades in Chapter 3 may be partly linked with *Equal To* trades buying/selling refreshed iceberg orders.

Table 4.7: Average Trade Size and Number of Observations for Active Trade Categories

This table reports the number and size of trade variable observations use in the No Change version of VAR Model 3 for each subgroup of stocks, broken down by subperiod. Each panel presents results for a specific stock group, with the first 6 columns containing trade size information and columns 7 to 12 reporting information about the number of trade observations. Columns 1 to 4 in each panel report the average size of *Greater Than Ex-No-Change* trades (*Greater Than* trades that are not also *No Change* trades), *Equal To Ex-No-Change* trades (*Equal To* trades that are no also *No Change* trades), *Less* trades (*Less Than* trades, by definition, do not reveal hidden liquidity and therefor have no *Ex-No-Change* variant), and *No-Change* trades for each stock group. For example, for the day subperiod on March 18th, the average size of *Greater Than Ex-No-Change* trades for Group 1 stocks is 1,296 shares. Column 5 presents the size difference between average *Greater Than Ex-No-Change* trades and average *Greater Than* with *No Change* trades. For example, for the day subperiod on March 18th for Group 1 stocks the difference is 5, meaning average *Greater Than Ex-No-Change* trades are 5 shares larger than *Greater Than* trades that include *No Change* trades. Column 6 repeats the analysis from column 5 for *Equal To* trades. Columns 7 through 10 present the average number of *Greater Than Ex-No-Change*, *Equal To Ex-No-Change*, *Less Than*, and *No Change* trades in each subgroup, respectively. For example, in the day subperiod of March 18th for Group 1 stocks, there are an average of 2,186 *Greater Than Ex-No-Change* trades per stock. Column 11 presents the differences in the average number of *Greater Than Ex-No-Change* trades and *Greater Than* trades that include *No Change* trades. For example, for the day subperiod of March 18th for Group 1 stocks, the difference is -281, meaning the average number of *Greater Than Ex-No-Change* trades is 281 less than the average number of *Greater Than* with *No Change* trades. Column 12 repeats the column 11 analysis for *Equal To* trades.

	Group 1 - Average Trade Size						**Group 1 - Average # Observations**					
	No Change Model				Difference		No Change Model				Difference	
Mar 18	Greater Than Ex-No-Change	Equal-To Ex-No-Change	Less Than	No Change	Greater Than	Equal To	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Greater Than	Equal To
Day	1,296	513	315	919	5	9	2,186	3,049	15,546	516	-281	-236
Morning	1,224	530	320	947	-4	13	814	1,116	5,096	222	-127	-95
Pre	1,325	583	352	983	21	-8	313	463	2,194	86	-45	-41
Post	1,309	476	300	869	1	12	1,059	1,470	8,256	208	-109	-99
Mar 19												
Day	1,278	533	322	917	12	6	1,681	2,414	13,254	592	-341	-251
Morning	1,246	488	314	906	11	6	1,093	1,538	7,698	341	-192	-148
Pre	1,283	628	322	923	26	12	310	488	2,698	113	-65	-48
Post	1,394	631	347	940	22	11	278	388	2,859	138	-84	-54

	Group 2 - Average Trade Size						**Group 2 - Average # Observations**					
	No Change Model				Difference		No Change Model				Difference	
Mar 18	Greater Than Ex-No-Change	Equal-To Ex-No-Change	Less Than	No Change	Greater Than	Equal To	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Greater Than	Equal To
Day	921	434	242	719	-7	-5	964	2,090	5,891	240	-97	-143
Morning	876	419	264	679	-9	5	376	764	2,071	96	-40	-56
Pre	924	574	252	847	-11	19	155	331	1,082	39	-16	-23
Post	958	423	221	716	4	-8	433	995	2,737	105	-41	-64
Mar 19												
Day	1,097	517	255	800	1	24	761	1,684	5,230	230	-99	-131
Morning	1,022	449	261	770	-10	8	446	939	2,503	115	-48	-67
Pre	1,260	671	236	825	71	117	150	380	1,271	56	-26	-30
Post	1,238	691	262	957	22	34	165	365	1,457	59	-25	-34

	Group 3 - Average Trade Size						Group 3 - Average # Observations					
	No Change Model				Difference		No Change Model				Difference	
Mar 18	Greater Than Ex-No-Change	Equal-To Ex-No-Change	Less Than	No Change	Greater Than	Equal To	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Greater Than	Equal To
Day	748	235	200	703	-84	-20	482	976	2,252	167	-65	-102
Morning	753	229	199	538	-43	-17	209	353	822	70	-25	-46
Pre	762	263	215	867	-126	-30	84	193	407	26	-8	-18
Post	732	231	194	741	-103	-17	189	429	1,023	71	-32	-39
Mar 19												
Day	900	269	221	659	-41	-23	444	858	2,190	214	-79	-136
Morning	908	258	221	657	-43	-31	224	430	925	95	-34	-62
Pre	829	279	208	655	-52	-13	111	221	539	54	-19	-35
Post	955	277	228	700	-7	-22	108	207	726	65	-26	-39

	Group 4 - Average Trade Size						Group 4 - Average # Observations					
	No Change Model				Difference		No Change Model				Difference	
Mar 18	Greater Than Ex-No-Change	Equal-To Ex-No-Change	Less Than	No Change	Greater Than	Equal To	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Greater Than	Equal To
Day	1,305	686	277	965	-117	36	145	345	888	67	-23	-44
Morning	1,258	527	277	1,041	-171	1	57	120	309	25	-8	-17
Pre	1,380	922	296	878	24	96	29	70	201	16	-4	-11
Post	1,325	717	282	1,006	-96	64	61	157	384	28	-9	-15
Mar 19												
Day	1,339	669	290	1,238	-149	-20	133	300	756	58	-21	-37
Morning	1,399	701	307	1,188	-114	27	71	150	347	32	-8	-15
Pre	1,343	764	274	1,337	-68	30	33	73	182	12	-3	-8
Post	1,457	692	294	2,059	-249	-64	34	80	248	17	-6	-11

The *No Change* trade impulse generates the smallest bid price return CIRFs of the active trades (Table 4.8), similar to the results for VAR Model 2. Interestingly, the *No Change* average trade size is between *Equal To* and *Greater Than* but the bid price return CIRFs are lower than the *Less than* trades. Neither *Less than* nor *No Change* trade impulses change the BBO price, but the market interprets less information flowing from the *No Change* trade despite its larger size.

Table 4.8: Active Trade Impulse Average Bid Return CIRFs

The following table reports the average bid return CIRFs caused by the trade impulses in the column header, segmented by subperiod and subgroup. Group 1 and Group 2 results are present in the first panel, with the second panel containing results for Group 3 and Group 4. In each panel, average bid return CIRFs are presented in columns 1 to 4, and 5 to 8 for each subgroup, respectively. In each 4 column set of subgroup results, the first column reports the average bid return CIRFs for a *Greater Than Ex-No-Change* impulse, the second column reports the average bid return CIRFs for an *Equal To Ex-No-Change* impulse, the third column reports the average bid return CIRFs for a *Less Than* impulse, and the fourth column reports the average bid return CIRFs for a *No Change* impulse. For example, for the day subperiod of March 18th for Group 1 stocks, the average bid return CIRF resulting from a *Greater Than Ex-No-Change* impulse is 0.020%; the *Equal To Ex-No-Change* impulse causes an average 0.027% bid return CIRF for the same subgroup in the same subperiod. For each average, a standard T-Statistic is calculated with the null

hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Average Bid Return CIRFs for Active Trade Impulses								
	Group 1				Group 2			
March 18	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	No Change	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	No Change
Day	0.020%	0.027%	0.012%	0.003%	0.044%	0.071%	0.031%	0.006%
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Morning	0.023%	0.031%	0.013%	0.001%	0.045%	0.066%	0.028%	0.006%
	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.02
Pre	0.021%	0.028%	0.010%	0.004%	0.041%	0.057%	0.022%	0.032%
	0.0	0.0	0.0	0.04	0.0	0.0	0.0	0.20
Post	0.019%	0.029%	0.012%	0.003%	0.045%	0.086%	0.038%	0.007%
	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.01
March 19								
Day	0.018%	0.023%	0.009%	0.002%	0.036%	0.059%	0.023%	0.004%
	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0
Morning	0.019%	0.026%	0.011%	0.002%	0.039%	0.070%	0.027%	0.007%
	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.15
Pre	0.018%	0.020%	0.009%	0.005%	0.032%	0.047%	0.022%	0.011%
	0.0	0.0	0.0	0.11	0.0	0.0	0.0	0.11
Post	0.016%	0.022%	0.008%	0.002%	0.032%	0.053%	0.020%	0.021%
	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.16

Average Bid Return CIRFs for Active Trade Impulses								
	Group 3				Group 4			
March 18	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	No Change	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	No Change
Day	0.060%	0.092%	0.042%	0.007%	0.121%	0.147%	0.055%	0.011%
	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.06
Morning	0.066%	0.118%	0.047%	0.009%	0.148%	0.180%	0.049%	0.015%
	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.17
Pre	0.048%	0.057%	0.023%	0.016%	0.087%	0.103%	0.019%	0.008%
	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.29
Post	0.056%	0.088%	0.043%	0.005%	0.109%	0.141%	0.054%	0.036%
	0.0	0.0	0.0	0.49	0.0	0.0	0.0	0.01
March 19								
Day	0.053%	0.081%	0.038%	0.008%	0.101%	0.150%	0.039%	0.012%
	0.0	0.0	0.0	0.14	0.0	0.0	0.0	0.01
Morning	0.064%	0.095%	0.048%	0.015%	0.106%	0.159%	0.036%	0.006%
	0.0	0.0	0.0	0.14	0.0	0.0	0.02	0.49
Pre	0.048%	0.071%	0.028%	0.003%	0.097%	0.145%	0.023%	0.014%
	0.0	0.0	0.0	0.46	0.0	0.0	0.05	0.10
Post	0.042%	0.070%	0.020%	0.005%	0.061%	0.094%	0.017%	0.014%
	0.0	0.0	0.0	0.10	0.0	0.0	0.0	0.01

Separating the *No Change* trades from the *Greater Than* and *Equal To* categories increases the bid price return CIRFs for the *Greater Than* and *Equal To* active trade impulses (Table 4.9). *Less than* trade impulses, however, have lower bid price return CIRFs. *Less than* trade impulse CIRFs are derived indirectly from the other active trade categories instead of directly from the initial impulse and subsequent *Less than* trades. The additional *No Change* category and its lower price impact have more influence on *Less than* trades as *No Change* trades displace some *Greater Than*

and *Equal To* order flow CIRF volume that was previously spawned by the *Less than* impulse. *Greater Than* and *Equal To* order flow CIRFs, in contrast, do not have significant *No Change* CIRFs (i.e. the *No Change* CIRFs for *Greater Than* and *Equal To* trade impulses are single digits) as illustrated in Table 4.10. The minimal *No Change* order flow CIRFs for *Greater Than* and *Equal To*, compared to the *No Change* trade impulse in Table 4.10, indicate that an active trade is unlikely to run into an iceberg order, but if an iceberg order is discovered it attracts follow-on active trades.

Table 4.9: Average Bid Return CIRF Changes

This table reports the difference in average bid returns CIRFs between *Greater Than Ex-No-Change*, *Equal To Ex-No-Change,* and *Less Than* trade variables in the No Change version of VAR Model 3 and *Greater Than*, *Equal To,* and *Less Than* trade variables that include *No Change* trades. Results are presented for each subperiod, with trios of columns containing data for each subgroup of stocks. Group 1 and Group 2 results are presented in the first panel, with the second panel reporting results for Group 3 and Group 4. The first column in each trio of columns presents the differences in the average bid return CIRFs between *Greater Than Ex-No-Change* and *Greater Than* trades that include *No Change* trades, with the second and third columns repeating the calculation for the difference in average bid return CIRFs between *Equal To Ex-No-Change* and *Equal To* trades that include *No Change* trades and *Less Than* trades in the two versions of VAR Model 3. For example, for the day subperiod of March 18th for Group 1 stocks, the difference between *Greater Than Ex-No-Change* average bid return CIRFs and *Greater Than* average bid return CIRFs is 0.0020%, meaning the average bid return CIRF caused by *Greater Than Ex-No-Change* trades is 0.0020% higher than the average bid return CIRF caused by *Greater Than* trades that include *No Change* trades.

	Average Bid Return CIRF Changes					
	Group 1			Group 2		
March 18	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change
Day	0.0020%	0.0013%	0.0000%	0.0039%	0.0065%	-0.0002%
Morning	0.0032%	0.0014%	-0.0001%	0.0040%	0.0058%	-0.0004%
Pre	0.0021%	0.0028%	-0.0001%	0.0033%	0.0070%	-0.0007%
Post	0.0016%	0.0013%	0.0000%	0.0041%	0.0056%	-0.0004%
March 19						
Day	0.0027%	0.0020%	-0.0001%	0.0036%	0.0056%	-0.0001%
Morning	0.0028%	0.0023%	-0.0001%	0.0031%	0.0075%	0.0000%
Pre	0.0021%	0.0014%	-0.0003%	0.0034%	0.0036%	-0.0001%
Post	0.0026%	0.0020%	-0.0001%	0.0038%	0.0054%	-0.0002%

	Average Bid Return CIRF Changes					
	Group 3			Group 4		
March 18	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than Ex-No-Change
Day	0.0118%	0.0138%	-0.0002%	0.0178%	0.0231%	-0.0015%
Morning	0.0095%	0.0199%	0.0011%	0.0204%	0.0279%	-0.0001%
Pre	0.0072%	0.0064%	-0.0009%	0.0074%	0.0165%	-0.0082%
Post	0.0109%	0.0094%	-0.0017%	0.0094%	0.0200%	0.0002%
March 19						
Day	0.0085%	0.0150%	-0.0008%	0.0191%	0.0245%	-0.0011%
Morning	0.0074%	0.0181%	-0.0009%	0.0036%	-0.0047%	-0.0119%
Pre	0.0104%	0.0128%	-0.0076%	0.0040%	0.0355%	-0.0053%
Post	0.0056%	0.0161%	0.0005%	0.0077%	0.0147%	-0.0013%

Table 4.10 presents the order flow CIRFs for the active trade impulses. Similar to VAR Model 3 in Chapter 3, *Less than* trade impulses produce the most follow-on trading activity, but now *No Change* impulses producing the second most additional trading. As in VAR Model 3 in Chapter 3, the *Greater Than* and *Equal To* impulses produce little subsequent trading activity, which means the market's order flow reaction is isolated to the *Less than* and *No Change* trade impulses; the market's trading reaction is restricted to impulses that do not change the BBO price. The VAR model produces a contradictory signal with respect to information about price, with an inverse relationship between the return CIRFs and the order flow CIRFs. The liquidity seeking behavior of the market is more pronounced when the trades are separated by size, compared to VAR Model 2, as the *No Change* impulse's largest response is from additional *No Change* orders – revelation of hidden liquidity attracts more trades despite a reduced likelihood of a price change. The *Greater Than* CIRFs reinforce this idea, since they are higher for *No Change* impulses than *Greater Than* and *Equal To* impulses (second only to the *Less than* impulse), indicating that the *Greater Than* trades are "feeling" their way through the market, polling the BBO for liquidity by attempting to trade more than the posted volume when there is an indication that there is more than the posted liquidity available. The passive order flow CIRFs for *No Change* impulses are opposite from the other active trade impulses, similar to VAR Model 2. These passive orders appear to be adding liquidity to the market when the iceberg order is identified, supporting the notion that liquidity begets liquidity.

Table 4.10: Active Trade Impulse Order Flow CIRFs

The table below presents the order flow CIRFs for a *No Change* trade impulse in each subperiod, with subgroup results presented in separate panels. The column headers indicate the specific order flow CIRF being presented in that column. For example, for the day subperiod of March 18th, a *No Change* trade impulse induces an order flow response of 56 shares for *Greater Than Ex-No-Change* trades (column 1 in the first panel) and -11 shares (i.e. sell of 11 shares) for *Equal To Ex-No-Change* trades (column 2 in the first panel). For each average, a standard T-Statistic is calculated with the null hypothesis that the average equals 0 and the alternative hypothesis that the average is not zero. P-values are presented below each table entry.

Group 1

Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse

	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Mar 18								
Day	56	-11	168	200	28	13	61	7
	0.0	0.14	0.0	0.0	0.41	0.09	0.09	0.01
Morning	58	-30	172	225	-18	9	122	7
	0.01	0.09	0.0	0.0	0.69	0.34	0.02	0.15
Pre	100	-9	96	180	129	20	177	11
	0.0	0.62	0.06	0.0	0.07	0.1	0.04	0.25
Post	28	0	190	183	31	13	-11	7
	0.03	0.94	0.0	0.0	0.65	0.12	0.78	0.12
Mar 19								
Day	45	-5	125	180	-45	-2	-26	3
	0.13	0.19	0.0	0.0	0.08	0.76	0.56	0.64
Morning	39	-4	151	177	-37	-12	-16	-1
	0.17	0.52	0.0	0.0	0.14	0.41	0.65	0.93
Pre	79	15	93	118	38	3	-107	4
	0.10	0.34	0.02	0.0	0.64	0.29	0.22	0.64
Post	16	-17	51	192	-152	11	145	7
	0.25	0.14	0.42	0.0	0.02	0.25	0.36	0.18

Group 2

Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse

	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Mar 18								
Day	57	20	285	312	0	22	49	12
	0.0	0.02	0.0	0.0	0.99	0.02	0.24	0.08
Morning	48	39	214	280	35	13	45	-3
	0.0	0.04	0.0	0.0	0.26	0.40	0.43	0.83
Pre	77	16	178	127	209	14	-127	92
	0.02	0.54	0.02	0.0	0.07	0.12	0.22	0.13
Post	64	20	387	337	-34	36	74	14
	0.0	0.0	0.0	0.0	0.59	0.0	0.23	0.10
Mar 19								
Day	43	15	275	200	-40	8	22	9
	0.0	0.11	0.0	0.0	0.50	0.43	0.48	0.19
Morning	17	19*	264	200	-91	7	63	7
	0.33	0.06	0.0	0.0	0.10	0.72	0.41	0.60
Pre	107	-4	268	227	-49	3	-291	59
	0.10	0.87	0.01	0.0	0.47	0.88	0.15	0.01
Post	90	60	476	172	29	72	-329	8
	0.17	0.07	0.02	0.0	0.76	0.09	0.18	0.31

Group 3

Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse

	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Mar 18								
Day	53	23	216	379	97	13	52	11
	0.16	0.09	0.0	0.0	0.30	0.47	0.16	0.66
Morning	69	9	237	265	45	25	52	36
	0.09	0.76	0.02	0.0	0.57	0.42	0.22	0.28
Pre	156	99	198	202	-39	145	64	24
	0.23	0.27	0.04	0.0	0.58	0.30	0.26	0.18
Post	53	7	252	301	181	22	-19	-11
	0.23	0.48	0.01	0.0	0.38	0.43	0.74	0.68

Mar 19								
Day	78	22	167	214	64	40	-40	21
	0.12	0.42	0.03	0.0	0.35	0.03	0.40	0.22
Morning	76	3	326	343	9	52	-92	11
	0.27	0.94	0.05	0.0	0.75	0.21	0.19	0.37
Pre	-14	16	65	144	162	36	5	37
	0.57	0.51	0.30	0.0	0.26	0.21	0.93	0.20
Post	34	28	79	115	29	56	32	7
	0.39	0.28	0.13	0.0	0.37	0.04	0.48	0.83

	Group 4							
	Average Order Flow CIRFs from 1,000 Share No Change Trade Impulse							
	Greater Than Ex-No-Change	Equal To Ex-No-Change	Less Than	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Mar 18								
Day	32	25	196	219	40	55	159	-17
	0.14	0.02	0.0	0.0	0.17	0.0	0.0	0.36
Morning	42	16	201	157	21	82	103	-6
	0.13	0.12	0.0	0.0	0.59	0.03	0.01	0.78
Pre	26	57	201	152	51	49	70	63
	0.58	0.04	0.1	0.0	0.39	0.05	0.38	0.45
Post	66	95	153	159	79	78	322	37
	0.02	0.02	0.0	0.0	0.01	0.02	0.01	0.67
Mar 19								
Day	57	17	121	209	-37	32	-29	29
	0.03	0.14	0.1	0.0	0.24	0.19	0.62	0.19
Morning	11	40	121	201	-29	3	1	35
	0.82	0.21	0.11	0.0	0.56	0.91	0.99	0.26
Pre	-48	48	67	58	-17	58	123	-1
	0.47	0.16	0.04	0.0	0.86	0.04	0.04	0.96
Post	74	44	138	131	2	71	0	2
	0.03	0.11	0.0	0.0	0.93	0.01	1.0	0.93

The different active trade categories provide a different perspective than the *Inflection* / *Non-Inflection* trade division, but the same conclusion. The order flow CIRFs support the idea that the market seeks liquidity and the information that VAR reveals is about order flow instead of prices (the more liquidity, the lower the price impact, regardless of actual permanent price movement), consistent with the conclusions of Buti et al. (2011), the multidimensional view of informed trading in O'Hara (2015), and the increased trading activity found by Frey and Sandås (2009) and Aitken et al. (2001). My analysis does not investigate iceberg orders directly, but the orders that interact with hidden liquidity, which indirectly indicates that the market does not view hidden liquidity as being informed, in line with Zhu (2014).

4.5: Rolling VAR Model Results

VAR models that analyze static blocks of data lose the ability to analyze the impact of market dynamics on the VAR information measure in favour of an averaging of effects over the time

periods that may be marked by very different influences. Applying the VAR model to a rolling subset of data that spans a period of time reveals new relationships between order flow, returns, and the VAR measures of information; the VAR model measures price volatility irrespective of permanent price change, which means it is not measuring information impounding. The Rolling VAR Model has three measures of returns, which are summarized in Table 4.11. The Midpoint Price change is the daily change of the midpoint price for each stock for each day (i.e. the change from the opening price to the closing price), averaged over each subgroup. The Average Net Bid Price Change is the average of the net bid price changes from the first to the last bid price for each observation block, which approximates the midpoint price change over the observations (plus or minus changes in the bid-ask spread). The Average Absolute Cumulative Bid Price Change is the average of the product of the absolute returns over each observation block. The Net Bid Price and Absolute Cumulative Bid Price Change are calculated by the following formulas:

$$Net\ Bid\ Price\ Change = \frac{Bid\ Price_N - Bid\ Price_0}{Bid\ Price_0} \qquad \textit{(eq 4.3)}$$

$$Absolute\ Cumulative\ Bid\ Price\ Change = \left(1 + abs\left[\frac{Bid\ Price_1 - Bid\ Price_0}{Bid\ Price_0}\right]\right)\left(1 + abs\left[\frac{Bid\ Price_2 - Bid\ Price_1}{Bid\ Price_1}\right]\right) \ldots \left(1 + abs\left[\frac{Bid\ Price_N - Bid\ Price_{N-1}}{Bid\ Price_{N-1}}\right]\right) - 1 \qquad \textit{(eq 4.4)}$$

where N is the number of observations in each observation block. The difference between the net and Absolute Cumulative bid price changes is the difference between distances measured "as the crow flies" and "as the road winds", respectively. Net bid price changes measure the difference between the starting and ending points (i.e. \$10 to \$12 to \$11 is a net bid price change of 10%) of each observation block, while the Absolute Cumulative bid price changes are the product of the absolute values of each price change with an observation block (i.e. \$10 to \$12 to \$11 is an Absolute Cumulative bid price change of 30%)[8]. The Absolute Cumulative bid price change increases relative to the midpoint and net bid price changes as liquidity falls from Group 1 to Group 4, indicating that less liquidity means the market does more "work", or has more volatility, to find its final net price change; there is more temporary price change in the process

[8] Net bid price change = \$11 / \$10 – 1 = 10%. Absolute Cumulative bid price change = (1 + abs((\$12 – \$10) / \$10)) x (1 + abs((\$11 - \$12) / \$12)) – 1 = 30%

of determining the permanent price change. The price discovery process is more efficient for more liquid stocks than for less liquid stocks, where efficiency is measured by the price "distance" that has to be traveled to arrive at the net price change.

Table 4.11: VAR Model 1 Rolling VAR Model return measures

This table reports the average of the net and absolute cumulative returns calculated for each observation block used in the Rolling VAR Model analysis for VAR Model 1, divided by subgroup (note: there are no subperiods in this analysis, the observation blocks cover all of each day's data). The Average Net Bid Price Change is the average change in price between the first and last bid prices in each observation block (compounding the Average Net Bid Price Change by the number of blocks in a day approximates the Midpoint Price Change for the day, plus/minus differences between midpoint and bid prices). For example, if the first bid price is 10.00, the second bid price is 9.90, and the third and last bid price is 10.20, the net bid price change is 2.0% ([10.20 ÷ 10.00] – 1). The Absolute Cumulative Bid Price Change is the result of compounding all of the absolute bid price changes in each observation block, which is total amount of price movement in the block. For example, if the first bid price is 10.00, the second bid price is 9.90, and the third and last bid price is 10.20, the absolute cumulative bid price change is 4.06% ([1 + 1%] x [1 + 3.03%] – 1). The Midpoint Price Change is the change in the Midpoint Price change for each day (i.e. the daily midpoint price change of the stocks in each subgroup).

	Average Return Measures				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change	0.33%	2.70%	0.33%	-1.27%	0.22%
Average Net Bid Price Change	0.01%	0.01%	0.00%	-0.03%	0.02%
Average Absolute Cumulative Bid Price Change	3.44%	1.66%	2.73%	5.78%	3.63%

The R^2 of the regression of Equation 4.1 the return measures against the CIRFs from each of the impulses for VAR Model 1 (*Trade*, Change of Existing Bid, and *New Bid*) are shown in Table 4.12, averaged for each subgroup. For example, the average R^2 for the regression of the Midpoint Price Change against the return CIRFs from the trade impulse is 0.10 for All stocks and 0.17 for Group 1. For all subgroups, the return CIRFs do the best job of explaining the changes in the absolute cumulative bid price changes over the course of a trading day, and not the net bid price change or the midpoint price change. The lack of explanatory power for midpoint and net bid price changes is counter to the intended purpose of the VAR model, as these measures of permanent price change are supposed to be caused by information impounding. Instead of price impact, however, the VAR model is measuring the amount of "work" required in the price discovery process, through the absolute cumulative change in the bid price. As the VAR model measures positive sequential relationships, the more total movement, the more sequential relationships that can be measured, which is captured by the higher return CIRFs, regardless of the final price change. This result is reinforced by the R^2 rising as liquidity falls (moving from Group 1 to Group

4), commensurate with the increase in the absolute cumulative bid price change relative to the net bid price and midpoint price changes. As liquidity falls, stocks need more price discovery "work" to arrive at the final price change. The more liquid the stock, the more direct the net price change relative to the absolute cumulative bid price change as the market spends less time searching for an equilibrium.

The passive order impulses have similar explanatory power to the active trades as liquidity falls, but active trades are relatively more informative for more liquid stocks. This may reflect the varying importance of active and passive orders in producing the price path as liquidity falls, with passive orders taking on more importance when there is less active trading. If liquidity is determined by the relatively scarce order flow, less liquid stocks may see a rise in the information content of passive orders which are relatively scarce in Groups 3 and 4 compared to Groups 1 and 2 (see Appendix 4.3).

Table 4.12: VAR Model 1 R^2

The table below presents the average R^2 for each subgroup of stocks of the simple linear regression *(eq 4.2)* of the Midpoint Price Change, Net Bid Price Change, and Absolute cumulative Bid Price Change return measures against the bid return CIRFs for *Trade*, *Change to Existing Bid*, and *New Bid* impulses in VAR Model 1. For example, the average R^2 for all stocks for the regression of Midpoint Price Change against the return CIRFs for the *Trade* impulse in VAR Model 1 is 0.22 (see the first column of the *Trade* Impulse row which is one row below Midpoint Price Change by row). Similarly, the average R^2 for all stocks of the regression of the Midpoint Price Change against the return CIRFs for the *Change to Existing Bid* impulse in VAR Model 1 is 0.21.

	Average R^2				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change by					
Trade Impulse	0.10	0.17	0.13	0.09	0.08
Change to Existing Bid Impulse	0.08	0.07	0.06	0.13	0.09
New Bid Impulse	0.01	0.02	0.01	0.07	0.00
Net Bid Price Change by					
Trade Impulse	0.11	0.17	0.13	0.11	0.09
Change to Existing Bid Impulse	0.09	0.07	0.06	0.15	0.09
New Bid Impulse	0.01	0.02	0.02	0.06	0.00
Absolute cumulative Bid Price Change by					
Trade Impulse	0.26	0.25	0.30	0.45	0.20
Change to Existing Bid Impulse	0.24	0.29	0.32	0.25	0.20
New Bid Impulse	0.13	0.06	0.14	0.17	0.13

The subgroup averages mask cross-sectional information. Table 4.13 reports the correlation of the return measures and R^2 for all stocks. The higher the correlation, the more the differences in

the return measures relate to the differences in the CIRFs (and vice versa). The highest correlation for all CIRFs is with the absolute cumulative bid price change, and lowest for Midpoint Price Change, regardless of impulse. The cross-sectional differences being best explained by the absolute cumulative bid price change and not the midpoint price change reinforces the idea that the VAR model is measuring the amount of work done in price discovery as opposed to the permanent price change.

Table 4.13: VAR Model 1 Cross-sectional correlations

This table reports the correlations between the return measures in the column headers and the R^2 results used to form Table 4.12 corresponding to the row headers for all stocks. For example, the *Trade* Impulse row under Midpoint Price Change by calculates the correlation of the R^2 from regressions of the Midpoint Price Change against the bid return CIRFs caused by a *Trade* impulse from VAR Model 1 with the Midpoint Price Change (column 1, correlation = -0.13), Average Net Bid Price Change (column 2, correlation = -0.01), Average Absolute cumulative Bid Price Change (column 3, correlation = 0.59), and Average Midpoint Price Change (column 4, correlation = -0.06) for all stocks. (i.e. for each stock we have its Midpoint Price Change and the R^2 from a regression of the Midpoint Price Change against the bid return CIRFs caused by a *Trade* impulse, which are inputs in the correlation calculation, yielding a correlation of -0.13). Average Midpoint Price Change is calculated in the same manner as Net Bid Price Change but using the Midpoint prices at the beginning and end of each block.

	Correlations - All			
	Midpoint Price Change	**Average Net Bid Price Change**	**Average Absolute cumulative Bid Price Change**	**Average Midpoint Price Change**
Midpoint Price Change by				
Trade Impulse	-0.05	-0.13	0.00	-0.11
Change to Existing Bid Impulse	-0.08	-0.08	0.06	-0.09
New Bid Impulse	0.04	0.10	0.23	0.09
Net Bid Price Change by				
Trade Impulse	-0.07	-0.12	-0.04	-0.12
Change to Existing Bid Impulse	-0.12	-0.09	0.10	-0.14
New Bid Impulse	0.06	0.09	0.26	0.10
Absolute cumulative Bid Price Change by				
Trade Impulse	-0.17	-0.15	0.22	-0.19
Change to Existing Bid Impulse	0.05	0.06	0.12	0.05
New Bid Impulse	0.08	0.16	0.26	0.15

The cross-sectional correlations are repeated for each subgroup (Table 4.14), which highlights the impact of liquidity on the VAR model results. Like the correlations with the entire group, the absolute cumulative bid price changes show the highest correlations across the different subgroups. The more liquid subgroups have more influence from active trade impulses while the less liquid subgroups are more influenced by passive order impulses, consistent with the results from the *No Change* models. Group 1 is unique in having high cross-sectional explanatory power

for midpoint and net bid price changes despite the lower average R^2 in Table 4.12. For the less liquid subgroups, the cross-sectional correlations are highest for the absolute cumulative bid price changes. Group 1 has roughly twice the order activity of Group 2 (see Appendix 4.3) as well as there being less variation in activity between subgroup members (Figure 3.1 in Chapter 3), which puts Group 1 in a unique position with respect to liquidity.

Cross-sectional differences in the R^2 are more readily explained by active trades and new bids than by changes in the existing bid, suggesting the more aggressively liquidity traders compete for liquidity the greater the difference in return CIRFs. Cross-sectional analysis in the literature focuses on firm characteristics like market value or trading activity (Brogaard et al., 2019; Hasbrouck, 1991) to explain differences in CIRFs. The cross-sectional analysis in this section uses net, absolute cumulative, and midpoint returns to explain the differences in R^2 of return CIRFs. Absolute cumulative returns generate materially higher explanatory power of the differences in R^2 than net or midpoint returns, suggesting the VAR model is more sensitive to the volatility of prices than to the permanent change in prices, which calls into question its information impounding accuracy. For the less liquid subgroups (3 and 4), the change in existing bid passive order flow has similar or higher cross-sectional correlations than active trades and *New Bids*. By absorbing active trades and reacting to new bids, the existing bids play a greater role in price discovery when liquidity is lower. The lower number of trades may be the result of lower volume at the existing BBO, inhibiting trading and causing larger spreads and more movement in the BBO to find liquidity, shifting the balance of negotiating power to the passive orders (i.e. active orders compete for passive orders). Particularly concerning for the combination of midpoint/net returns and the VAR model to measure information flow is the negative correlations Table 4.14 which indicate that larger returns are commensurate with lower explanatory power for the VAR model CIRFs. If information impounding causes net price changes and more information causes larger net price changes, the VAR model CIRFs should pick up the greater information flow and account for at least as much of the change in prices, not less. Instead, only the absolute cumulative bid price return measure has consistently positive correlations, aside from Group 1 regressions with Midpoint and Net Bid price changes as dependent variables. The VAR Model only reliably

measures the cumulative changes of a stock's price (the sum of the up-and-down price movements, not the end results of the up-and-down price movements), and not the information content of those price changes.

Table 4.14: VAR Model 1 Subgroup Correlations

This table reports the correlations between the return measures in the column headers and the R^2 results used to form Table 4.12 corresponding to the row headers for each stock subgroup (this table replicates the analysis from Table 4.13, but for the stock subgroups instead of all stocks). The first panel presents results for Group 1 (columns 1 to 4) and Group 2 (columns 5 to 8) stocks, the second panel for stock Groups 3 (columns 1 to 4) and 4 (columns 5 to 8). For example, in the first panel the *Trade* Impulse row under Midpoint Price by calculates the correlation of the R^2 from regressions of the Midpoint Price Change against the bid return CIRFs caused by a *Trade* impulse from VAR Model 1 with the Midpoint Price Change (column 1, correlation = 0.32), Average Net Bid Price Change (column 2, correlation = 0.34), Average Absolute cumulative Bid Price Change (column 3, correlation = 0.11), and Average Midpoint Price Change (column 4, correlation = 0.35) for Group 1 stocks (i.e. for each stock in Group 1 we have its Midpoint Price Change and the R^2 from a regression of the Midpoint Price Change against the bid return CIRFs caused by a *Trade* impulse, which are inputs in the correlation calculation, yielding a correlation of 0.32). Average Midpoint Price Change is calculated in the same manner as Net Bid Price Change but using the Midpoint prices at the beginning and end of each block.

	Correlations - Group 1				Correlations - Group 2			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Trade Impulse	0.08	0.13	-0.22	0.12	-0.05	-0.01	-0.03	0.01
Change to Existing Bid Impulse	0.22	0.27	0.43	0.27	-0.11	0.02	-0.10	0.00
New Bid Impulse	-0.18	-0.22	-0.29	-0.24	-0.09	0.01	0.00	-0.01
Net Bid Price Change by								
Trade Impulse	0.12	0.18	-0.20	0.16	-0.06	-0.02	-0.04	0.00
Change to Existing Bid Impulse	-0.23	-0.26	-0.42	-0.27	-0.08	0.06	-0.07	0.04
New Bid Impulse	-0.19	-0.23	-0.27	-0.24	-0.06	0.06	0.01	0.04
Absolute cumulative Bid Price Change by								
Trade Impulse	-0.43	-0.45	0.25	-0.45	-0.22	-0.27	0.41	-0.27
Change to Existing Bid Impulse	-0.28	-0.30	-0.35	-0.31	0.03	0.01	0.09	0.01
New Bid Impulse	-0.06	-0.07	0.51	-0.05	0.06	0.10	0.14	0.11

	Correlations - Group 3				Correlations - Group 4			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Trade Impulse	-0.33	-0.33	0.37	-0.33	-0.10	-0.10	0.01	-0.09
Change to Existing Bid Impulse	0.44	0.48	0.18	0.48	-0.17	-0.19	-0.03	-0.20
New Bid Impulse	0.34	0.43	0.42	0.40	0.08	0.09	0.19	0.07

Net Bid Price Change by								
Trade Impulse	-0.45	-0.44	0.35	-0.45	-0.09	-0.06	-0.07	-0.08
Change to Existing Bid Impulse	0.40	0.42	0.22	0.42	-0.20	-0.18	-0.01	-0.24
New Bid Impulse	0.31	0.35	0.49	0.33	0.12	0.08	0.25	0.10
Absolute cumulative Bid Price Change by								
Trade Impulse	-0.03	-0.16	0.23	-0.12	-0.14	-0.06	0.13	-0.14
Change to Existing Bid Impulse	0.20	0.28	-0.20	0.24	0.09	0.07	0.34	0.05
New Bid Impulse	0.28	0.40	0.04	0.39	0.15	0.14	0.32	0.13

The Rolling VAR model tells a story of efficiency, as measured by the amount of price discovery activity required for a given change in price. Keeping the R^2 and correlation results in context with the price moves in Table 4.11, the VAR model CIRFs are not related to permanent price changes, but liquidity. More liquid stocks incur lower volatility finding a new equilibrium price, represented by the difference between the net and absolute cumulative price changes (smaller absolute cumulative price changes relative to net price changes), regardless of the magnitude of the price move, suggesting that liquidity is the bandwidth of a stock to incorporate information. For the most liquid stocks in Group 1, the bandwidth is wide enough to absorb large price changes without requiring additional "work" compared to less liquid stocks in Group 4 which require larger absolute cumulative price changes to incorporate information leading to smaller price moves.

The number of blocks used in the regressions of the *Trade*, *Change to Existing Bid*, and *New Bid* CIRFs against the Absolute cumulative Bid Price Change return measure is summarized in Table 4.15. The drop in the minimum number of blocks in Group 4 reflects the inclusion of lower liquidity stocks that have fewer observations per day. Even in the most liquid subgroups, however, there are cases of missing blocks due to return CIRF results that are more than 15 standard deviations from average. Keeping in mind that these blocks are comprised of 1,000 observations, there are periods within a day in which 1,000 observations are insufficient to produce a meaningful result (e.g. in some cases the order flow or return CIRFs are too large to be considered realistic, such as 88,000 or 220,000 trade CIRFs for a 1,000 share trade impulse, or order flow CIRFs of 0 for all variables except the initial impulse). These excluded blocks are preceded and succeeded by blocks with acceptable (i.e. non-outlier) results, suggesting that differences in observations over incrementally different time periods can cause significant

differences in results. In the subperiods defined in Chapters 2 and 3 these problems were not apparent but may have only been masked by diluting the problematic observational blocks in a larger dataset. It may be that these disturbances, which are present across all stock subgroups, are affecting the VAR results for large data sets without being noticed.

Table 4.15: VAR Model 1 Regression Block Summary Statistics

The following table presents summary statistics for the number of observation blocks used in VAR Model 1 for the *Trade*, *Change to Existing Bid*, and *New Bid* impulses. The summary statistics include the minimum, median, mean, and maximum number of observation blocks for each stock subgroup. 30 is the minimum number of observation blocks for Groups 1, 2, and 3, but drops to 20 for Group 4 given the lower number of observations. For example, for the VAR Model 1 results created by the *Trade* impulse, the stock with minimum number of observation blocks from the entire group of stocks used 20 blocks, while the minimum number of blocks for Group 1 stocks is 110.

	Number of Blocks for Absolute cumulative Bid Change Regressions				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Trade Impulse					
Minimum	20	110	36	30	20
Median	30	197	103	30	30
Mean	73	216	120	39	31
Max	334	334	332	84	62
Change to Existing Bid Impulse					
Minimum	20	110	36	30	20
Median	30	197	103	30	30
Mean	73	216	120	39	31
Max	334	334	332	84	62
New Bid Impulse					
Minimum	20	110	36	30	20
Median	30	197	103	30	30
Mean	73	216	120	39	31
Max	334	334	332	84	62

The Rolling VAR model results for VAR Models 2 and 3 mirror those of VAR Model 1, and only the active trading variables are shown the tables below (full results are included in Appendix 4.4 and Appendix 4.5, respectively). The separation of trades into their respective categories for VAR models 2 and 3 creates a different set of blocks which are excluded as outliers. The impact is evident in the different price change averages in Table 4.16 compared to Table 4.11. Absolute cumulative price changes show the largest difference as they include all the differences in blocks while midpoint and net bid price changes are only sensitive to changes in the first and last price in a block.

Table 4.16: VAR Model 2 and 3 Rolling VAR Model return measures

This table reports the average of the net and absolute cumulative returns calculated for the observation blocks used in the Rolling VAR Model analysis for VAR Model 2 and VAR Model 3, divided by subgroup (note: there are no subperiods in this analysis, the observation blocks cover all of each day's data). The VAR Model 2 average return measures are in the first panel with the VAR Model 3 average returns in the second panel. The Average Net Bid Price Change is the average change in price between the first and last bid prices in each observation block (compounding the Average Net Bid Price Change by the number of blocks in a day approximates the Midpoint Price Change for the day, plus/minus differences between midpoint and bid prices). For example, if the first bid price is 10.00, the second bid price is 9.90, and the third and last bid price is 10.20, the net bid price change is 2.0% ([10.20 ÷ 10.00] – 1). The Absolute cumulative Bid Price Change is the result of compounding all of the absolute bid price changes in each observation block, which is total amount of price movement in the block. For example, if the first bid price is 10.00, the second bid price is 9.90, and the third and last bid price is 10.20, the absolute cumulative bid price change is 4.06% ([1 + 1%] x [1 + 3.03%] – 1). The Midpoint Price Change is the change in the Midpoint Price change for each day (i.e. the daily midpoint price change of the stocks in each subgroup). Average Net Bid and Absolute cumulative Bid return measures are different for VAR Model 2 compared to VAR Model 3 (and compared to VAR Model 1 in Table 4.11) because inclusion of different numbers of variables alters the beginning and end points of each observation block.

	VAR Model 2 Average				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change	0.33%	2.70%	0.33%	-1.27%	0.22%
Average Net Bid Price Change	0.01%	0.01%	0.00%	-0.03%	0.02%
Average Absolute cumulative Bid Price Change	3.44%	1.66%	2.73%	5.78%	3.63%

	VAR Model 3 Average				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change	0.32%	2.70%	0.33%	-1.27%	0.21%
Average Net Bid Price Change	0.01%	0.01%	0.00%	-0.03%	0.02%
Average Absolute cumulative Bid Price Change	3.44%	1.66%	2.73%	5.78%	3.63%

The average R^2 for VAR Models 2 and 3 (Table 4.17) are similar, though slightly smaller, than the averages for VAR Model 1 (Table 4.12), but that may be due to the increased number of variables in the regressions. *Inflection* trades show more variation in explanatory power between subgroups for midpoint and net bid price returns, which was hidden in the *Trade* variable in VAR Model 1. All trade types exhibit increased explanatory power as liquidity falls, as seen with VAR Model 1, but interestingly all trade types show the same level of explanatory power for absolute cumulative price changes. *Inflection* and *Non-Inflection* trades having the same cross-sectional explanatory power recalls the lack of distinction between the first trade of a sequence and subsequent trades in Chapters 2 and 3. Sequence does not matter if the market attaches equal importance to all trades in a sequence and cannot detect information from either momentum or contrarian trading strategies. *Trade* sizes are also the same for absolute cumulative bid price changes, despite the return CIRF differences observed in Chapter 3. If *Equal To* trades have the

largest price impact and *Less than* trades have the greatest amount of follow-on trading, why would price changes be equally explained by any of the trade size CIRFs? If the return CIRFs measure information and return differences between stocks are the result of different levels of information impounding, presumably more influential (i.e. larger) return CIRFs would explain more of the cross-sectional differences. Stock returns appear to be equally influenced by large and small return CIRFs, calling into question the meaning of the return CIRF or treating the return CIRFs like risk factors necessitating the calculation of a stock's sensitivity to each return CIRF.

Table 4.17: VAR Model 2 and 3 R^2 for Active Trading Variables

The table below presents the average R^2 for each subgroup of stocks of the simple linear regression *(eq 4.2)* of the Midpoint Price Change, Net Bid Price Change, and Absolute cumulative Bid Price Change return measures against the bid return CIRFs for *Inflection* and *Non-Inflection* trade impulses for VAR Model 2 (first panel) and *Greater Than, Equal To,* and *Less Than* trade impulses for VAR Model 3 (second panel). For example, the average R^2 for all stocks in VAR Model 2 for the regression of Midpoint Price Change against the return CIRFs for the *Inflection* trade impulse in VAR Model 2 is 0.22 (see the first column of the *Trade* Impulse row which is one row below Midpoint Price Change by row). Similarly, the average R^2 for all stocks of the regression of the Midpoint Price Change against the return CIRFs for the *Non-Inflection* trade impulse in VAR Model 2 is 0.31.

	VAR Model 2 Average R^2				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change by					
Inflection Trade Impulse	0.02	0.03	0.01	-0.02	0.04
Non-Inflection Trade Impulse	0.12	0.17	0.15	0.12	0.09
Net Bid Price Change by					
Inflection Trade Impulse	0.04	0.03	0.01	-0.01	0.06
Non-Inflection Trade Impulse	0.13	0.17	0.15	0.12	0.11
Absolute cumulative Bid Price Change by					
Inflection Trade Impulse	0.24	0.25	0.21	0.39	0.22
Non-Inflection Trade Impulse	0.24	0.17	0.26	0.33	0.22

	VAR Model 3 Average R^2				
	All	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Midpoint Price Change by					
Greater Than Trade Impulse	0.01	0.06	0.03	0.02	-0.01
Equal To Trade Impulse	0.07	0.13	0.09	0.13	0.03
Less Than Trade Impulse	0.02	0.04	0.05	0.07	-0.02
Net Bid Price Change by					
Greater Than Trade Impulse	0.02	0.06	0.03	0.01	0.00
Equal To Trade Impulse	0.07	0.13	0.09	0.12	0.05
Less Than Trade Impulse	0.02	0.04	0.05	0.08	-0.01
Absolute cumulative Bid Price Change by					
Greater Than Trade Impulse	0.19	0.13	0.14	0.38	0.19
Equal To Trade Impulse	0.19	0.11	0.19	0.32	0.18
Less Than Trade Impulse	0.11	0.05	0.13	0.16	0.10

The cross-sectional correlations in Table 4.18 display the same pattern of correlations as VAR Model 1 in Table 4.13. The highest correlations between the R^2 and absolute cumulative bid prices, regardless of which return measure is used to generate the adjust R^2. The closeness of the correlations between trade categories for absolute cumulative bid price changes and the negative correlations for the other return categories reinforces the earlier discussion that cross-sectional differences are not related to the size of the CIRFs and therefore the meaning of the CIRFs is ambiguous.

Table 4.18: VAR Model 2 and VAR Model 3 Cross-sectional correlations

This table reports the correlations between the return measures in the column headers and the R^2 results used to form Table 4.17 corresponding to the row headers for all stocks in VAR Model 2 (first panel) and VAR Model 3 (second panel). For example, the *Inflection* Trade Impulse row under Midpoint Price Change by calculates the correlation of the R^2 from regressions of the Midpoint Price Change against the bid return CIRFs caused by an *Inflection* trade impulse from VAR Model 2 with the Midpoint Price Change (column 1, correlation = -0.13), Average Net Bid Price Change (column 2, correlation = 0.04), Average Absolute cumulative Bid Price Change (column 3, correlation = 0.68), and Average Midpoint Price Change (column 4, correlation = -0.05) for all stocks. (i.e. for each stock we have its Midpoint Price Change and the R^2 from a regression of the Midpoint Price Change against the bid return CIRFs caused by an *Inflection* trade impulse, which are inputs in the correlation calculation, yielding a correlation of -0.13). Average Midpoint Price Change is calculated in the same manner as Net Bid Price Change but using the Midpoint prices at the beginning and end of each observation block.

	VAR Model 2 Correlations - All			
	Midpoint Price Change	**Average Net Bid Price Change**	**Average Absolute cumulative Bid Price Change**	**Average Midpoint Price Change**
Midpoint Price Change by				
Inflection Trade Impulse	-0.06	-0.04	-0.03	-0.06
Non-Inflection Trade Impulse	-0.06	-0.13	-0.10	-0.12
Net Bid Price Change by				
Inflection Trade Impulse	-0.06	-0.03	-0.03	-0.05
Non-Inflection Trade Impulse	-0.11	-0.18	-0.14	-0.19
Absolute cumulative Bid Price Change by				
Inflection Trade Impulse	-0.08	-0.03	0.20	-0.03
Non-Inflection Trade Impulse	-0.24	-0.22	0.06	-0.27

	VAR Model 3 Correlations - All			
	Midpoint Price Change	**Average Net Bid Price Change**	**Average Absolute cumulative Bid Price Change**	**Average Midpoint Price Change**
Midpoint Price Change by				
Greater Than Trade Impulse	-0.05	-0.12	0.17	-0.10
Equal To Trade Impulse	-0.08	-0.12	0.02	-0.10
Less Than Trade Impulse	-0.07	-0.14	0.09	-0.11

Net Bid Price Change by				
Greater Than Trade Impulse	-0.06	-0.11	0.15	-0.11
Equal To Trade Impulse	-0.07	-0.12	-0.02	-0.09
Less Than Trade Impulse	-0.09	-0.17	0.05	-0.14
Absolute cumulative Bid Price Change by				
Greater Than Trade Impulse	-0.16	-0.13	0.25	-0.16
Equal To Trade Impulse	-0.15	-0.14	0.20	-0.11
Less Than Trade Impulse	0.01	0.13	0.09	0.06

The cross-sectional correlations for each subgroup in Table 4.19 show the negative correlations disappear for absolute cumulative bid price changes across all regression regardless of the return measure used to generate the R^2. The midpoint and net bid price R^2 correlations for the *Trade* variable in Table 4.14 are driven by *Inflection* and not *Non-Inflection* trades, but combining them in one trade category caused a misleading correlation. This may be due to arbitrage trading that is reversing local trends in response to trades in the US market, although this effect does not appear in the absolute cumulative bid price change regression adjust R^2 results. Different subgroups have different correlations for trade sizes, breaking the uniformity in Table 4.18, but without any apparent pattern besides a loose relationship between liquidity and trade size. In subgroup 1 the most influential trade size is *Greater Than*, but for subgroups 2 and 3 it is *Equal To*, and *Less than* for subgroup 4; perhaps as liquidity falls there is more cross-sectional explanatory value to smaller trades. The fact that there are no notable differences in the Rolling VAR Models for VAR Models 2 and 3 is the interesting result – the lack of cross-sectional differences outside of liquidity rejects the price information interpretation of the VAR Model CIRFs.

Table 4.19: VAR Model 2 Subgroup Correlations

This table reports the correlations between the return measures in the column headers and the R^2 results used to form Table 4.17 corresponding to the row headers for each stock subgroup (this table replicates the analysis from Table 4.18, but for the stock subgroups instead of all stocks). The first panel presents results for Group 1 (columns 1 to 4) and Group 2 (columns 5 to 8) stocks for VAR Model 2, the second panel for stock Groups 3 (columns 1 to 4) and 4 (columns 5 to 8) for VAR Model 2, the third panel presents results for Group 1 (columns 1 to 4) and Group 2 (columns 5 to 8) stocks for VAR Model 3, and the fourth panel for stock Groups 3 (columns 1 to 4) and 4 (columns 5 to 8) for VAR Model 3. For example, in the first panel the *Inflection* Trade Impulse row under Midpoint Price by calculates the correlation of the R^2 from regressions of the Midpoint Price Change against the bid return CIRFs caused by an *Inflection* trade impulse from VAR Model 2 with the Midpoint Price Change (column 1, correlation = -0.17), Average Net Bid Price Change (column 2, correlation = -0.19), Average Absolute cumulative Bid Price Change (column 3, correlation = 0.50), and Average Midpoint Price Change (column 4, correlation = -0.19) for Group 1 stocks in VAR Model 2 (i.e. for each stock in Group 1 in VAR Model 2 we have its Midpoint Price Change and the R^2 from a regression of the Midpoint Price Change against the bid return CIRFs caused by an *Inflection* trade impulse, which are inputs in

the correlation calculation, yielding a correlation of -0.17). Average Midpoint Price Change is calculated in the same manner as Net Bid Price Change but using the Midpoint prices at the beginning and end of each observation block.

	VAR Model 2 Correlations - Group 1				VAR Model 2 Correlations - Group 2			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Inflection Trade Impulse	-0.29	-0.33	0.15	-0.33	-0.10	-0.11	0.06	-0.10
Non-Inflection Trade Impulse	0.12	0.08	-0.45	0.07	0.03	0.07	0.02	0.09
Net Bid Price Change by								
Inflection Trade Impulse	-0.29	-0.32	0.14	-0.33	-0.10	-0.11	0.08	-0.10
Non-Inflection Trade Impulse	0.19	0.15	-0.48	0.14	0.02	0.05	0.01	0.08
Absolute cumulative Bid Price Change by								
Inflection Trade Impulse	-0.41	-0.44	-0.05	-0.44	-0.16	-0.18	0.42	-0.17
Non-Inflection Trade Impulse	-0.20	-0.22	0.56	-0.20	-0.31	-0.38	0.45	-0.39

	VAR Model 2 Correlations - Group 3				VAR Model 2 Correlations - Group 4			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Inflection Trade Impulse	0.05	0.05	0.15	0.03	-0.10	-0.08	-0.04	-0.08
Non-Inflection Trade Impulse	-0.11	-0.11	0.21	-0.10	-0.14	-0.14	-0.13	-0.14
Net Bid Price Change by								
Inflection Trade Impulse	0.03	0.08	0.11	0.04	-0.09	-0.07	-0.06	-0.08
Non-Inflection Trade Impulse	-0.24	-0.26	0.20	-0.25	-0.22	-0.18	-0.20	-0.22
Absolute cumulative Bid Price Change by								
Inflection Trade Impulse	-0.08	-0.20	0.25	-0.17	0.08	0.08	0.09	0.07
Non-Inflection Trade Impulse	-0.10	-0.10	-0.21	-0.10	-0.28	-0.21	-0.03	-0.27

	VAR Model 3 Correlations - Group 1				VAR Model 3 Correlations - Group 2			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Greater Than Trade Impulse	0.01	0.13	-0.05	-0.51	-0.15	-0.18	0.14	-0.16
Equal To Trade Impulse	-0.40	-0.51	0.38	-0.15	-0.21	-0.33	-0.17	-0.31
Less Than Trade Impulse	-0.02	-0.16	0.13	-0.24	-0.24	-0.27	0.27	-0.26
Net Bid Price Change by								

Greater Than Trade Impulse	-0.01	0.11	-0.06	0.10	-0.14	-0.16	0.14	-0.15
Equal To Trade Impulse	-0.39	-0.51	0.42	-0.50	-0.21	-0.32	-0.18	-0.31
Less Than Trade Impulse	-0.05	-0.18	0.18	-0.17	-0.23	-0.24	0.28	-0.23
Absolute cumulative Bid Price Change by								
Greater Than Trade Impulse	-0.46	-0.45	0.01	-0.45	-0.11	-0.16	0.41	-0.15
Equal To Trade Impulse	-0.54	-0.60	0.42	-0.60	-0.23	-0.28	0.44	-0.30
Less Than Trade Impulse	-0.05	-0.18	0.33	-0.18	-0.24	-0.28	0.33	-0.28

	VAR Model 3 Correlations - Group 3				**VAR Model 3 Correlations - Group 4**			
	Midpoint Price Change	**Average Net Bid Price Change**	**Average Absolute cumulative Bid Price Change**	**Average Midpoint Price Change**	**Midpoint Price Change**	**Average Net Bid Price Change**	**Average Absolute cumulative Bid Price Change**	**Average Midpoint Price Change**
Midpoint Price Change by								
Greater Than Trade Impulse	-0.29	-0.30	0.44	-0.32	-0.06	-0.08	0.20	-0.07
Equal To Trade Impulse	0.16	0.14	-0.03	0.16	-0.08	-0.12	0.06	-0.11
Less Than Trade Impulse	-0.41	-0.42	0.50	-0.43	-0.03	-0.08	0.01	-0.05
Net Bid Price Change by								
Greater Than Trade Impulse	-0.28	-0.27	0.38	-0.29	-0.08	-0.08	0.20	-0.09
Equal To Trade Impulse	0.15	0.15	-0.03	0.16	-0.07	-0.11	0.01	-0.09
Less Than Trade Impulse	-0.42	-0.43	0.50	-0.45	-0.06	-0.11	-0.05	-0.08
Absolute cumulative Bid Price Change by								
Greater Than Trade Impulse	-0.11	-0.25	0.20	-0.22	-0.10	-0.07	0.11	-0.11
Equal To Trade Impulse	-0.03	-0.18	0.42	-0.13	-0.03	-0.08	0.01	-0.04
Less Than Trade Impulse	0.20	0.27	-0.21	0.23	0.08	0.16	0.11	0.07

4.6: Conclusions

The goal of Chapter 4 is to delve deeper into the trading pattern and liquidity questions raised by Chapter 3. This Chapter investigates the impact of a new variable for the VAR model that isolates trading activity specifically driven by liquidity seeking behavior to find an explanation for the apparent divergence between observed returns and the VAR model's return CIRFs. With respect to liquidity, the genesis of the analysis in this Chapter is *Greater Than* trades having lower return CIRFs than *Equal To* trades and similar return CIRFs to *Less Than* trades in Chapter 3. A new variable, *No Change*, is created for trades that equal or exceed the size of the prevailing bid or ask when the trade is executed but there is no change to the bid or ask price. This new variable contributes to the literature by producing a more granular understanding of the price discovery process, specifying a portion of the endogenous trading activity in Chapters 2 and 3 as liquidity seeking. If the identified endogenous trading contributes to the return CIRF but is also

uninformed, interpreting the return CIRFs as measuring informed trading is problematic. The presence of the *No Change* variable also reduces the endogenous order flow of certain other trading variables, implying the literature overestimates the amount of informed trading measured by the VAR model. The Rolling VAR model analyzes the relationship between the return CIRFs and different measures of observed returns by calculating return CIRFs and different return measures over a series of observation blocks that incrementally advance over the dataset. Regressing the return measures against the return CIRFs finds the return CIRFs have the highest explanatory power for the absolute cumulative return measure (which compounds the absolute value of all return observations) instead of the midpoint price return. This adds to the literature by providing evidence that the VAR model is not measuring net (permanent) price change over a period of time, but the total amount of price change during a period of time (temporary) and supports the liquidity impact conclusions from Chapter 3. If the VAR model is measuring the amount of "work" done by the market in the price discovery process instead of its outcome, we may need to update the interpretation of the return CIRFs currently present in the literature.

Combining the conclusions from the *No Change* and Rolling VAR models, there is a distinction between measures of Order Flow and Price information, both of which could underlie informed trading and associated measures of information (O'Hara, 2015). In both cases, return CIRFs and trade CIRFs do not coincide, with the former not being supported by the market's trading reaction and the latter not corresponding to price impact. The *No Change* trades produce order flow responses consistent with informed trading, but without any corresponding price impact. The market appears to be treating the *No Change* orders as informed about liquidity, but not price (Buti et al., 2011), inciting follow-on trading activity as found by Aitken et al. (2001) and Bacidore et al. (2003). My analysis adds to this literature by illustrating how the observed trading activity impacts the VAR model CIRFs, revealing the order flow versus value information dichotomy. The Rolling VAR model results bring the relationship between cumulative price change and the VAR model CIRFs to the fore, suggesting the VAR model is measuring liquidity rather than information about value. Liquidity differences reinforce these results, with more liquid subgroups producing lower price impact but higher order flow measures. VAR does not appear to measure information

about prices, only information about order flow. Initial analysis from the Rolling VAR model suggests potential new research into, or re-examination of, price discovery and our methods of measuring information impounding. For example, the reduced information measures of the VAR model observed by Collin-Dufresne and Fos (2015) may be the result of informed traders reducing the absolute cumulative price path on days on which they are trading, reducing the observed volatility as the price moves to a new equilibrium. Further research into the uniformity of cross-sectional correlations could investigate the possibility of changing sensitivities of returns to order flow or possibly uncover an alternative mechanism that causes information to be processed at constant rate regardless of order flow, perhaps related to a fixed factor like time. It may be that the market's price and order flow response is situationally specific and involves more complex patterns than prima facia market data (i.e. certain combinations of passive and active trades may have different price or order flow response than the same activity combined differently).

4.7: Chapter 4 References

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4.8: Chapter 4 Appendix

Appendix 4.1: Time Weighted Bid and Ask Sizes by Group

	Group 1		Group 2		Group 3		Group 4	
March 18	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size	Time Weighted Bid Size	Time Weighted Ask Size
Day	2,646	2,921	1,707	1,722	711	752	2,069	2,166
Morning	2,336	2,666	1,573	1,431	634	719	2,061	2,112
Pre	2,778	2,987	2,007	2,000	791	846	2,355	2,274
Post	2,919	3,200	1,512	1,779	717	678	1,710	2,102
March 19								
Day	2,927	3,414	1,892	2,005	778	774	2,280	2,230
Morning	2,704	2,894	1,622	1,844	743	625	1,942	1,879
Pre	2,816	3,404	1,905	1,969	793	759	2,138	2,257
Post	3,389	4,171	2,261	2,281	808	1,004	2,947	2,698

Appendix 4.2: Inflection and Non-Inflection Ex-No-Change Trade Impulse Order Flow CIRFs

	Group 1						
	1,000 Share Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-96	150	4	173	25	-177	22
Morning	-94	154	9	188	26	-213	27
Pre	-95	145	7	171	28	-271	29
Post	-97	149	-1	160	22	-142	18
Day	-88	141	7	213	18	-182	20
Morning	-97	138	9	180	18	-142	16
Pre	-64	124	2	283	23	-276	26
Post	-99	167	8	257	18	-223	23

	Group 1						
	1,000 Share Non-Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-74	359	27	288	45	-249	33
Morning	-57	331	37	298	39	-300	33
Pre	-63	223	12	335	38	-270	32
Post	-85	423	27	277	53	-210	35
Day	-63	326	38	278	26	-332	33
Morning	-62	345	38	241	21	-293	29
Pre	-59	289	26	381	38	-427	44
Post	-69	308	46	328	34	-402	37

	Group 2						
	1,000 Share Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-123	253	8	173	48	-207	43
Morning	-128	245	7	162	40	-182	34
Pre	-116	245	15	183	46	-264	41
Post	-121	259	6	173	57	-203	50
Day	-94	199	3	183	44	-195	43
Morning	-98	190	2	145	46	-154	27
Pre	-86	184	4	205	37	-194	52
Post	-93	226	8	236	39	-286	69

	Group 2
	1,000 Share Non-Inflection Ex-No-Change Trade Impulse

	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-78	472	36	250	70	-227	55
Morning	-81	466	35	207	56	-214	52
Pre	-69	379	27	291	59	-328	47
Post	-80	503	44	281	87	-215	57
Day	-69	406	37	248	54	-237	53
Morning	-75	397	38	180	54	-189	48
Pre	-61	364	22	326	54	-271	64
Post	-63	438	42	337	52	-346	62

	Group 3						
	1,000 Share Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-134	249	21	54	42	-113	28
Morning	-134	296	29	28	28	-76	33
Pre	-128	145	-26	31	19	-85	21
Post	-138	230	23	90	62	-135	4
Day	-109	222	-7	79	41	-83	25
Morning	-107	218	7	92	49	-61	30
Pre	-97	264	16	75	27	-61	-10
Post	-101	192	-33	47	27	-113	32

	Group 3						
	1,000 Share Non-Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-93	420	65	176	92	-126	47
Morning	-95	377	50	134	89	-62	38
Pre	-102	270	39	146	63	-165	18
Post	-62	428	72	190	99	-185	72
Day	-74	373	56	125	45	-126	52
Morning	-56	311	53	50	12	-103	44
Pre	-70	331	65	199	52	-105	25
Post	-96	342	27	188	60	-154	50

	Group 4						
	1,000 Share Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-106	198	-2	59	52	-90	73
Morning	-100	174	-4	21	40	-71	59
Pre	-74	145	8	51	35	-66	49
Post	-91	156	-1	78	50	-79	47
Day	-100	225	30	43	37	-93	58
Morning	-86	188	54	51	37	-72	77
Pre	-82	229	38	55	24	-64	20
Post	-64	179	-4	36	9	-71	46

	Group 4						
	1,000 Share Non-Inflection Ex-No-Change Trade Impulse						
	Inflection Ex-No-Change	Non-Inflection Ex-No-Change	No Change	Change to Existing Bid	New Bid	Change to Existing Ask	New Ask
Day	-77	280	44	112	83	-31	55
Morning	-63	253	57	81	67	-37	59
Pre	-57	211	34	94	49	-25	24
Post	-62	245	30	121	74	-49	47

Day	-72	241	40	73	48	-76	39
Morning	-62	227	68	52	52	-88	18
Pre	-48	141	17	53	26	-85	19
Post	-75	191	30	70	29	-57	38

Appendix 4.3: Active and Passive Order Activity by SubGroup

Average Number of Observations - Group 1							
	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
18 Day	21,298	84,291	6,647	9,974	84,860	6,638	10,082
18 Morning	7,249	30,184	2,176	3,421	37,619	2,483	3,725
18 Pre	3,056	19,614	859	1,361	18,375	871	1,385
18 Post	10,994	34,493	3,612	5,192	28,866	3,284	4,973
19 Day	17,941	80,205	4,678	7,284	89,548	5,232	7,872
19 Morning	10,669	43,916	3,058	4,716	46,694	3,489	5,177
19 Pre	3,608	22,412	935	1,445	23,265	981	1,490
19 Post	3,664	13,877	685	1,123	19,589	762	1,205

Average Number of Observations - Group 2							
	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
18 Day	9,186	36,989	8,095	9,958	41,209	8,642	10,534
18 Morning	3,308	12,388	2,602	3,310	16,567	3,241	3,946
18 Pre	1,607	9,024	1,074	1,375	9,638	1,155	1,468
18 Post	4,271	15,577	4,419	5,273	15,004	4,246	5,121
19 Day	7,906	39,847	7,081	8,562	41,581	6,735	8,218
19 Morning	4,003	18,062	4,053	4,877	17,762	3,785	4,634
19 Pre	1,857	12,354	1,657	1,980	10,846	1,486	1,803
19 Post	2,046	9,430	1,371	1,705	12,974	1,465	1,781

VAR Model 2 Regression Block Summary Statistics

Average Number of Observations - Group 3							
	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
18 Day	3,877	8,175	2,792	3,648	10,053	2,916	3,857
18 Morning	1,455	2,451	1,112	1,456	3,309	1,137	1,498
18 Pre	709	2,146	396	553	2,357	463	646
18 Post	1,713	3,578	1,284	1,639	4,388	1,316	1,713
19 Day	3,707	8,941	2,487	3,281	8,288	2,409	3,223
19 Morning	1,675	3,623	1,431	1,813	3,456	1,418	1,833
19 Pre	925	2,764	563	772	2,042	569	775
19 Post	1,107	2,555	492	696	2,790	423	615

Average Number of Observations - Group 4							
	Trade	Change to Existing Bid	New Bid	Bid Price Change	Change to Existing Ask	New Ask	Ask Price Change
18 Day	1,417	4,910	1,447	1,730	4,226	1,233	1,536
18 Morning	502	1,461	597	703	1,442	532	640
18 Pre	310	1,431	232	290	1,086	202	263
18 Post	605	2,018	618	737	1,698	499	633
19 Day	1,248	4,189	1,208	1,463	4,222	1,123	1,396
19 Morning	578	1,744	672	800	1,779	627	760
19 Pre	294	1,191	282	341	1,310	263	333
19 Post	375	1,255	254	321	1,134	232	303

Appendix 4.4: VAR Model 2 Rolling VAR Model Results

VAR Model 2 Rolling VAR Model return measures

	Average				
	All	Group 1	Group 2	Group 3	Group 4
Midpoint Price Change	0.33%	2.70%	0.33%	-1.27%	0.22%
Average Net Bid Price Change	0.01%	0.01%	0.00%	-0.03%	0.02%
Average Absolute cumulative Bid Price Change	3.44%	1.66%	2.73%	5.78%	3.63%

VAR Model 2 R^2

	Average R2				
	All	Group 1	Group 2	Group 3	Group 4
Midpoint Price Change by					
Inflection Trade Impulse	0.02	0.03	0.01	-0.02	0.04
Non-Inflection Trade Impulse	0.12	0.17	0.15	0.12	0.09
Change to Existing Bid Impulse	0.09	0.08	0.07	0.08	0.10
New Bid Impulse	0.02	0.02	0.01	0.04	0.03
Net Bid Price Change by					
Inflection Trade Impulse	0.04	0.03	0.01	-0.01	0.06
Non-Inflection Trade Impulse	0.13	0.17	0.15	0.12	0.11
Change to Existing Bid Impulse	0.10	0.09	0.07	0.11	0.12
New Bid Impulse	0.02	0.02	0.01	0.04	0.03
Absolute cumulative Bid Price Change by					
Inflection Trade Impulse	0.24	0.25	0.21	0.39	0.22
Non-Inflection Trade Impulse	0.24	0.17	0.26	0.33	0.22
Change to Existing Bid Impulse	0.27	0.25	0.31	0.26	0.25
New Bid Impulse	0.14	0.07	0.12	0.17	0.15

VAR Model 2 Cross-sectional correlations

	Correlations - All			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by				
Inflection Trade Impulse	-0.06	-0.04	-0.03	-0.06
Non-Inflection Trade Impulse	-0.06	-0.13	-0.10	-0.12
Change to Existing Bid Impulse	0.01	0.01	-0.06	0.03
New Bid Impulse	0.10	0.17	0.07	0.18
Net Bid Price Change by				
Inflection Trade Impulse	-0.06	-0.03	-0.03	-0.05
Non-Inflection Trade Impulse	-0.11	-0.18	-0.14	-0.19
Change to Existing Bid Impulse	-0.03	-0.02	-0.01	-0.04
New Bid Impulse	0.15	0.21	0.08	0.24
Absolute cumulative Bid Price Change by				
Inflection Trade Impulse	-0.08	-0.03	0.20	-0.03
Non-Inflection Trade Impulse	-0.24	-0.22	0.06	-0.27
Change to Existing Bid Impulse	-0.01	-0.02	0.09	-0.02
New Bid Impulse	0.09	0.17	0.19	0.18

VAR Model 2 Subgroup Correlations

	Correlations - Group 1				Correlations - Group 2			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Inflection Trade Impulse	-0.29	-0.33	0.15	-0.33	-0.10	-0.11	0.06	-0.10
Non-Inflection Trade Impulse	0.12	0.08	-0.45	0.07	0.03	0.07	0.02	0.09
Change to Existing Bid Impulse	-0.19	-0.27	-0.17	-0.28	0.04	0.17	-0.05	0.16
New Bid Impulse	-0.18	-0.22	-0.30	-0.23	-0.07	-0.03	-0.03	-0.03
Net Bid Price Change by								
Inflection Trade Impulse	-0.29	-0.32	0.14	-0.33	-0.10	-0.11	0.08	-0.10
Non-Inflection Trade Impulse	0.19	0.15	-0.48	0.14	0.02	0.05	0.01	0.08
Change to Existing Bid Impulse	-0.20	-0.27	-0.18	-0.27	0.07	0.21	-0.01	0.19
New Bid Impulse	-0.17	-0.20	-0.27	-0.21	-0.04	0.00	-0.03	0.00
Absolute cumulative Bid Price Change by								
Inflection Trade Impulse	-0.41	-0.44	-0.05	-0.44	-0.16	-0.18	0.42	-0.17
Non-Inflection Trade Impulse	-0.20	-0.22	0.56	-0.20	-0.31	-0.38	0.45	-0.39
Change to Existing Bid Impulse	-0.16	-0.19	-0.27	-0.20	0.00	-0.04	0.09	-0.04
New Bid Impulse	-0.06	-0.08	0.57	-0.06	-0.03	-0.01	0.11	0.00

	Correlations - Group 3				Correlations - Group 4			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Inflection Trade Impulse	0.05	0.05	0.15	0.03	-0.10	-0.08	-0.04	-0.08
Non-Inflection Trade Impulse	-0.11	-0.11	0.21	-0.10	-0.14	-0.14	-0.13	-0.14
Change to Existing Bid Impulse	0.32	0.43	0.17	0.41	-0.01	-0.06	-0.13	-0.03
New Bid Impulse	0.48	0.54	0.35	0.54	0.14	0.13	0.00	0.14
Net Bid Price Change by								
Inflection Trade Impulse	0.03	0.08	0.11	0.04	-0.09	-0.07	-0.06	-0.08
Non-Inflection Trade Impulse	-0.24	-0.26	0.20	-0.25	-0.22	-0.18	-0.20	-0.22
Change to Existing Bid Impulse	0.24	0.34	0.25	0.31	-0.07	-0.09	-0.10	-0.10
New Bid Impulse	0.50	0.55	0.30	0.55	0.21	0.18	0.04	0.21
Absolute cumulative Bid Price Change by								
Inflection Trade Impulse	-0.08	-0.20	0.25	-0.17	0.08	0.08	0.09	0.07
Non-Inflection Trade Impulse	-0.10	-0.10	-0.21	-0.10	-0.28	-0.21	-0.03	-0.27
Change to Existing Bid Impulse	0.14	0.20	-0.38	0.17	-0.01	-0.04	0.26	-0.04
New Bid Impulse	0.37	0.51	0.10	0.49	0.18	0.15	0.18	0.17

	Number of Blocks for Absolute cumulative Bid Change Regressions				
	All	Group 1	Group 2	Group 3	Group 4
Inflection Trade Impulse					
Minimum	8	110	36	30	8
Median	30	197	102	30	30
Mean	72	215	120	39	30
Max	332	332	330	82	62
Non-Inflection Trade Impulse					
Minimum	9	110	36	30	9
Median	30	197	102	30	30
Mean	72	216	120	39	30
Max	334	334	329	82	62
Change to Existing Bid Impulse					
Minimum	9	110	36	30	9
Median	30	197	102	30	30
Mean	72	216	120	39	30
Max	334	334	330	82	62
New Bid Impulse					
Minimum	8	110	36	30	8
Median	30	197	102	30	30
Mean	72	215	120	39	30
Max	334	334	330	82	62

Appendix 4.5: VAR Model 3 Rolling VAR Model Results

VAR Model 3 Rolling VAR Model return measures

	Average				
	All	Group 1	Group 2	Group 3	Group 4
Midpoint Price Change	0.32%	2.70%	0.33%	-1.27%	0.21%
Average Net Bid Price Change	0.01%	0.01%	0.00%	-0.03%	0.02%
Average Absolute cumulative Bid Price Change	3.44%	1.66%	2.73%	5.78%	3.63%

VAR Model 3 R^2

	Average R2				
	All	Group 1	Group 2	Group 3	Group 4
Midpoint Price Change by					
Greater Than Trade Impulse	0.01	0.06	0.03	0.02	-0.01
Equal To Trade Impulse	0.07	0.13	0.09	0.13	0.03
Less Than Trade Impulse	0.02	0.04	0.05	0.07	-0.02
Change to Existing Bid Impulse	0.07	0.07	0.07	0.07	0.08
New Bid Impulse	-0.04	0.02	-0.01	0.05	-0.09
Net Bid Price Change by					
Greater Than Trade Impulse	0.02	0.06	0.03	0.01	0.00
Equal To Trade Impulse	0.07	0.13	0.09	0.12	0.05
Less Than Trade Impulse	0.02	0.04	0.05	0.08	-0.01
Change to Existing Bid Impulse	0.08	0.07	0.07	0.10	0.09
New Bid Impulse	-0.04	0.02	-0.02	0.05	-0.08
Absolute cumulative Bid Price Change by					
Greater Than Trade Impulse	0.19	0.13	0.14	0.38	0.19
Equal To Trade Impulse	0.19	0.11	0.19	0.32	0.18
Less Than Trade Impulse	0.11	0.05	0.13	0.16	0.10
Change to Existing Bid Impulse	0.27	0.32	0.32	0.28	0.24
New Bid Impulse	0.13	0.06	0.11	0.21	0.13

VAR Model 3 Cross-sectional correlations

	Correlations - All			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by				
Greater Than Trade Impulse	-0.05	-0.12	0.17	-0.10
Equal To Trade Impulse	-0.08	-0.12	0.02	-0.10
Less Than Trade Impulse	-0.07	-0.14	0.09	-0.11
Change to Existing Bid Impulse	0.11	0.15	0.04	0.17
New Bid Impulse	0.08	0.09	0.15	0.09
Net Bid Price Change by				
Greater Than Trade Impulse	-0.06	-0.11	0.15	-0.11
Equal To Trade Impulse	-0.07	-0.12	-0.02	-0.09
Less Than Trade Impulse	-0.09	-0.17	0.05	-0.14
Change to Existing Bid Impulse	0.05	0.10	0.04	0.08
New Bid Impulse	0.10	0.11	0.10	0.12
Absolute cumulative Bid Price Change by				
Greater Than Trade Impulse	-0.16	-0.13	0.25	-0.16
Equal To Trade Impulse	-0.15	-0.14	0.20	-0.11
Less Than Trade Impulse	0.01	0.13	0.09	0.06
Change to Existing Bid Impulse	0.01	0.06	0.04	0.06
New Bid Impulse	0.10	0.20	0.20	0.20

VAR Model 3 Subgroup Correlations

	Correlations - Group 1				Correlations - Group 2			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Greater Than Trade Impulse	0.01	0.13	-0.05	-0.51	-0.15	-0.18	0.14	-0.16
Equal To Trade Impulse	-0.40	-0.51	0.38	-0.15	-0.21	-0.33	-0.17	-0.31
Less Than Trade Impulse	-0.02	-0.16	0.13	-0.24	-0.24	-0.27	0.27	-0.26
Change to Existing Bid Impulse	-0.22	-0.24	-0.28	-0.28	0.12	0.21	-0.17	0.20
New Bid Impulse	-0.21	-0.27	0.10	-0.75	-0.07	-0.03	-0.11	-0.03
Net Bid Price Change by								
Greater Than Trade Impulse	-0.01	0.11	-0.06	0.10	-0.14	-0.16	0.14	-0.15
Equal To Trade Impulse	-0.39	-0.51	0.42	-0.50	-0.21	-0.32	-0.18	-0.31
Less Than Trade Impulse	-0.05	-0.18	0.18	-0.17	-0.23	-0.24	0.28	-0.23
Change to Existing Bid Impulse	-0.23	-0.24	-0.28	-0.24	0.12	0.24	-0.14	0.22
New Bid Impulse	-0.21	-0.26	0.10	-0.27	-0.03	0.00	-0.12	0.00
Absolute cumulative Bid Price Change by								
Greater Than Trade Impulse	-0.46	-0.45	0.01	-0.45	-0.11	-0.16	0.41	-0.15
Equal To Trade Impulse	-0.54	-0.60	0.42	-0.60	-0.23	-0.28	0.44	-0.30
Less Than Trade Impulse	-0.05	-0.18	0.33	-0.18	-0.24	-0.28	0.33	-0.28
Change to Existing Bid Impulse	-0.39	-0.39	-0.20	-0.40	-0.12	-0.19	0.21	-0.19
New Bid Impulse	-0.04	-0.13	0.61	-0.11	0.01	0.07	0.09	0.08

	Correlations - Group 3				Correlations - Group 4			
	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change	Midpoint Price Change	Average Net Bid Price Change	Average Absolute cumulative Bid Price Change	Average Midpoint Price Change
Midpoint Price Change by								
Greater Than Trade Impulse	-0.29	-0.30	0.44	-0.32	-0.06	-0.08	0.20	-0.07
Equal To Trade Impulse	0.16	0.14	-0.03	0.16	-0.08	-0.12	0.06	-0.11
Less Than Trade Impulse	-0.41	-0.42	0.50	-0.43	-0.03	-0.08	0.01	-0.05
Change to Existing Bid Impulse	0.40	0.50	0.22	0.48	0.15	0.10	0.03	0.13
New Bid Impulse	0.31	0.37	0.14	0.37	0.12	0.12	0.21	0.10
Net Bid Price Change by								
Greater Than Trade Impulse	-0.28	-0.27	0.38	-0.29	-0.08	-0.08	0.20	-0.09
Equal To Trade Impulse	0.15	0.15	-0.03	0.16	-0.07	-0.11	0.01	-0.09
Less Than Trade Impulse	-0.42	-0.43	0.50	-0.45	-0.06	-0.11	-0.05	-0.08
Change to Existing Bid Impulse	0.36	0.44	0.24	0.41	0.06	0.05	0.00	0.03
New Bid Impulse	0.33	0.38	0.11	0.38	0.16	0.14	0.13	0.14
Absolute cumulative Bid Price Change by								
Greater Than Trade Impulse	-0.11	-0.25	0.20	-0.22	-0.10	-0.07	0.11	-0.11
Equal To Trade Impulse	-0.03	-0.18	0.42	-0.13	-0.03	-0.08	0.01	-0.04
Less Than Trade Impulse	0.20	0.27	-0.21	0.23	0.08	0.16	0.11	0.07
Change to Existing Bid Impulse	0.01	0.07	-0.29	0.03	0.16	0.12	0.13	0.13
New Bid Impulse	0.24	0.38	0.07	0.36	0.22	0.22	0.19	0.22

VAR Model 3 Regression Block Summary Statistics

	Number of Blocks for Absolute cumulative Bid Change Regressions				
	All	Group 1	Group 2	Group 3	Group 4
Greater Than Trade Impulse					
Minimum	7	110	36	30	7
Median	30	196	102	30	28
Mean	71	214	115	39	28
Max	329	329	311	81	56
Equal To Trade Impulse					
Minimum	6	110	36	30	6
Median	30	196	102	30	28
Mean	71	214	114	39	28
Max	329	329	306	81	55
Less Than Trade Impulse					
Minimum	6	110	36	30	6
Median	30	196	102	30	28
Mean	71	214	114	39	28
Max	330	330	306	81	55
Change to Existing Bid Impulse					
Minimum	6	110	36	30	6
Median	30	196	102	30	28
Mean	71	214	114	39	28
Max	330	330	306	81	55
New Bid Impulse					
Minimum	6	110	36	30	6
Median	30	195	102	30	28
Mean	71	214	114	39	28
Max	330	330	306	81	55

Chapter 5: Conclusion

5.1: Results Summary

Understanding the flow of information into prices is fundamental to our understanding of how prices are formed (Hasbrouck, 1991). Without a reliable means of measuring the flow of information it is difficult to understand the price discovery process upon which so many asset-pricing and investment decisions are based (O'Hara, 2003). This thesis concludes that the VAR model from Hasbrouck (1991) has a number of flaws which can be overcome by augmenting the VAR model with the additional variables identified in this thesis. This thesis concludes that trading patterns impact the VAR model, as postulated in the research objectives for this research, contributing to the literature by proposing a number of specific variables that add to the VAR model's explanatory power and our understanding of the price discovery process.

Chapter 2 finds that the form of data used in the VAR model impacts its results. Including or excluding trading volume and consolidating the data by netting trading volumes over periods of time alter the CIRFs produced by the VAR model, in some cases by a factor of 2x or 3x, despite all of the data being identical in its raw form and nominally describing the same price changes. Trading patterns that characterize the data, such as *Inflection* trades and the length of serial correlated buys or sells, have significant explanatory power for the VAR model's CIRFs, despite not having any relationship to price changes. This conclusion contributes to the literature by detailing the sensitivity of the VAR model to factors that do not describe price changes, arguing against the VAR model as a reliable measure of information impounding (Spencer, 1989) if it does not explicitly include variables that account for the identified trading patterns. These results point the way to an expanded view of the variables that affect information measurement, which are explored further in Chapter 3.

The expanded VAR models in Chapter 3 conclude that passive order flow (Brogaard et al., 2019) and trading patterns (Keim and Madhavan, 1995) found in the data are significant contributors

to the VAR model's CIRFs. VAR models that exclude these factors are at risk of generating inaccurate estimates information impounding by misallocating the effects of the missing variables and generalizing causation that can be more narrowly attributed to specific order types, creating a blurred understanding of the price discovery process. Chapter 3 contributes further to the literature by decomposing the CIRFs to show the contribution of each variable in the VAR model, uncovering the complex mechanism at work in price discovery and the dependence of price change on combinations of orders instead of singular autoregressive series. This previously unexplored aspect of the VAR model adds to the literature by challenging the traditional view of the VAR model's information impounding accuracy by finding contradictions between order flow and price reactions to shocks; whether the market reacts to an impulse as being informed or uninformed depends on the choice of response variable, making the interpretation of the VAR model's CIRFs ambiguous without additional understanding of the mechanism at work, as presented in Chapter 3. Grouping the stocks in the dataset by liquidity finds a unique relationship between the CIRFs and liquidity – the greater the liquidity, the lower the variation in CIRFs across stocks and time periods, irrespective of price changes. Once liquidity reaches a certain level, the CIRFs become almost constant and cannot be a measure of information impounding as we normally conceive. Although Chapter 3 adds a number of important advances to the literature, the Chapter identifies but does not resolve the implications of the liquidity conundrum on information impounding. Perhaps we need a different VAR model for different levels of liquidity, akin to using a stopwatch or a radar to measure speeds at different scales.

The trading pattern and liquidity conclusions of Chapter 3 are further advanced in Chapter 4 which finds that a portion of the endogenous order flow forecast by the VAR model is liquidity seeking, being a reaction to the discovery of hidden liquidity (Frey and Sandås, 2009), and the CIRFs bear a strong relationship to price volatility separate from net price change. The literature is expanded by Chapter 4's conclusion that endogenous order flow variables in a VAR model that do not explicitly model hidden liquidity could cause the CIRFs to overestimate the information effect of trading activity, reducing the veracity of the VAR model's information measurement. The CIRF decomposition reveals that liquidity seeking endogenous trading, if not explicitly

modelled with the additional variable proposed in Chapter 4, could be attributed to other trading variables which creates an overestimate of the price impact of those other trading variables. A more definitive addition to the literature is made by the Rolling VAR model analysis that concludes that the VAR model is most closely related to a measure of the compounded absolute price changes over a period of time than the net change in price over a period of time, meaning the VAR model measures *how* a price changes, not *how much* a price change. The VAR model produces larger CIRFs for stocks with volatile trading regardless of the size of the net price change. The Rolling VAR analysis reveals that the VAR model measures the amount of "work" the market does in the price discovery process, rather than its outcome. The VAR model may be more a measure information processing efficiency, with efficiency relating to liquidity. The VAR model's information measure having little relationship with permanent price change when liquidity is introduced into the analysis suggests that the VAR model may be measuring the impact of liquidity on price volatility (O'Hara, 2015), and we need to conceive a new VAR model that accounts for liquidity differences between stocks.

5.2: Limitations and Implications for Future Research

There are a number of limitations to the analysis in this thesis, some of which can be overcome with additional research. The dataset is very specific to a moment in time, spanning only two days in the depth of the financial crisis, one of which includes an announcement by the Federal Open Market Committee. More data that covers a longer time period, possibly across multiple market cycles (either in totality or via periodic sampling), could produce different results that increase our understanding of the VAR model. It may also be interesting to discover if the CIRFs change over time in some relation to changes in market and economic conditions (is the liquidity impact on the CIRFs specific to 2009, is it constant across years, or does it ebb and flow in bull and bear markets?). Expanding the dataset presents practical issues, especially for computation of a large number of VAR models as in the Rolling VAR analysis, which consumed a (near) top-of-the-line desktop 24 hours a day for over two weeks to analyze only two days of data; access to high powered computing facilities could help address this number-crunching constraint.

Similarly, the CIRFs are estimated over a relatively short period of time, 100 ticks, which may be too short a time to apply the adjective "permanent" to the forecast price change, despite the CIRFs reaching a point of stability within the 100 tick range. This thesis measures responses to a fixed impulse size, but different order types occur with different frequency and size such that we are comparing CIRFs on a per-share basis when it may be more appropriate to use impulses that factor in the total number or volume of an order type; if the price impact of a *Less Than* trade is half that of an *Equal To* trade, but there are 10x the number of *Less Than* trades, do they really have less price impact? Perhaps a more realistic approach would include multiple (typical / expected / randomly generated) impulses over a longer number of ticks to simulate a more realistic price change forecast. Maybe we should not focus on the price impact of a trade impulse, but the price impact of a trade impulse followed by a new order at the best bid or ask, or some other combination of impulses. If markets respond to certain combinations of orders, instead of variables composed of series of individual observations we could create variables that define specific sequences of events (much like a three of a kind and a two of kind in poker have different values separately than when held together to form a full house). The impact of different trading venues on information impounding is also an area that could be explored further. The essays in this thesis noted material differences in VAR model output for cross-listed stocks and non-cross-listed stocks, which may relate to differences in liquidity, trading behavior, or information. An expanded VAR model that incorporated order flow series from multiple marketplaces may produce interesting results, possibly revealing identifiable information dissemination as found in Hasbrouck (1995). Multiple venue VAR models should include passive order flow variables to explicitly include the influence of arbitrage and explore how arbitrage trades propagate through the order flow variables that comprise the market. Markets characterized by high degrees of fragmentation could benefit from this research direction, with possible applications to different products with the same underlying asset, such as indices and their related ETFs and derivatives.

5.3: Chapter 5 References

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