Algorithmic trading and the liquidity of the JSE

Fabio Antonio Zito

13403011

A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Business Administration.

29 January 2014

Abstract

This study investigates the relationship between algorithmic trading and a change in market structure. Furthermore, the study aims to determine if there is a relationship between algorithmic trading and the liquidity of the JSE.

The level of algorithmic trading is measured through an algorithmic trading proxy based on current academic theory. The results illustrate that there is a strong statistical relationship between the AT proxy and a change in market structure.

The relationship between algorithmic trading and the liquidity of JSE is measured via four specific low-frequency measures: the stock turnover ratio, the proportional bid ask spread, the price impact ratio, and the zero return measure. Each liquidity measure is able to quantify a specific component of liquidity.

Each liquidity measure was regressed against the algorithmic trading proxy. The results attained were mixed, with only two of the four measures producing statistically significant relationships. The results seem to indicate that the increase in algorithmic activity has resulted in a reduction of the price impact effect; however, a parallel increase in volatility was observed. An increase in the zero return measure was observed, which indicates that AT increases the efficiency of trading by reducing trading costs, and gathering information at a faster rate.

The findings of this study may indicate that liquidity has improved, but has done so with a repercussion of an increase in volatility. Certain regulatory policy adjustments may be required to curb volatility while maintaining the heightened level of liquidity.

Key Words: Algorithmic Trading; Johannesburg Stock Exchange; Market Structure and Liquidity

Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

_____   29 January 2014

Signed: Fabio A. Zito   Date

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ACKNOWLEDGEMENT

To Craig Miller, thank for supervising my research. Thank you for the constant encouragement, interest in my research topic and patience. You went well beyond what any student can expect from his supervisor and I feel privileged to have worked with you over the past couple of months.

To the staff at the GIBS Info Center, thank you for all your help in answering all my questions regarding referencing and other thesis relation questions.

To the staff at the Johannesburg Stock Exchange, thank you for all you efficient and friendly responses to all my requests for data. I would like to thank Chester Enslin who helped me in my search for data.

To my fellow MBA classmates and friends, thank you for your help in getting through a challenging but enjoyable year. A special thank you to my syndicate, without them this MBA journey would have been a hell of a lot tougher and without any laughter. To Chad, Matt and Daniel thanks for all your support.

Finally, the biggest thanks must goes to my parents, Luigi and Dorothy. Without their patience and support I would never have attempted such and difficult task. Thank you for all the encouragement and motivational talks which got me through the year.

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Abbreviated Words

(ASX) - Australian Stock Market

(AT) - Algorithmic trading

(ATs) - Algorithmic traders

(BOVESPA) - Bolsa de Valores, Mercadorias & Futuros de São Paulo "Brazilian Stock Exchange"

(CFTC) - U.S.Commodity Futures Trading Commission

(DAX) - Deutscher Aktien Index

(DOT) - Designated order turnaround

(HFT) - High frequency trading

(HFTs) - High frequency traders

(JET) - Johannesburg Equities Trading System

(JSE) - Johannesburg Stock Exchange

(LOT) - Lesmond, Ogden and Trzcinka measure

(LSE) - London Stock Exchange

(NSE) - National Stock Exchange of India

(NYSE) - New York Stock Exchange

Glossary

Adverse selection – Is regarded a market failure and occurs due to an undesired results between and buy and a seller due to asymmetric information i.e. the buyer and seller have access to different information.

Buy side institutions – Unit trusts, pension funds and insurance companies form part of the buy side entities as they are inclined to buy shares for money-management purposes.

Fill rate – Is the percentage of a limit order that will be executed e.g. if a limit order of 100 shares is placed into the market and only 80 shares at traded the fill rate will be 80%.

Inside quote – Is the best bid and ask price offered by the market maker or specialist. The inside quote is the price a market order will be executed at.

Limit order - Is an order placed into the market to buy or sell a fixed amount of shares at a specified price or better.

Make and take fees - refers to the maker-taker pricing scheme, this is an incentive scheme that rewards liquidity suppliers (who place limit order) and charges liquidity demanders (who place market orders).

Market order - Is an order which instructs a financial intermediary to buy or sell shares at the best available price.

Order driven markets – Is a stock exchange where buyers and sellers display the price and amount of shares they wish to buy or sell.

Quote driven markets – Is a stock exchange which displays only the bids and asks of the market maker or specialist.

Sell side institutions – Are institutions that provide buy side entities information pertaining to the investments e.g. They provide target prices, recommendations for upgrades, downgrades and opinion.

1. Introduction to Research Problem

1.1 Background

Technological advances over the past decades have led to revolution in the way securities and other financial instruments are traded. Jones (2013) states that;

> "Before the advent of computers, all trading was conducted between humans, often in person on a trading floor. Back offices were filled with clerks and others to ensure that transactions were properly completed. Gradually, both the back office and the actual trading process have been transformed by automation." (p. 4)

Leinweber (2007) postulates that the first step in automating the trading process occurred in 1980. It was the first time since the 1920s that there had been such a technological upgrade in the way trading occurs. This breakthrough came in the form of the designated order turnaround (DOT) system. DOT was the first electronic execution system and was introduced by the New York Stock Exchange (NYSE). After this, algorithmic trading (AT) was one step away. Leinweber (2007) cites that early adopters of AT in the 1980s and 1990s employed complex Lotus 1-2-3 spread sheets in order to split large orders into smaller sized orders. This gave rise to first primitive trading algorithm.

Market structure improvements continued throughout the 1990s, especially in electronic communication networks, which considerably reduced order transmission times. In 2001, at the International Joint Conference on Artificial Intelligence, a group of IBM researchers presented their findings regarding AT vs. human trading. Das, Hanson, Kephart, & Tesauro, (2001) illustrated that their AT system had outperformed human subjects. In reaction, many major financial institutions began to invest in and employ AT.

At first, AT simply involved splitting and submitting of large orders into small orders, but then evolved and grew into market-making activities and event arbitrage activities. Growth of AT use has led to increases in stock market liquidity over the past decade (Hendershott, Jones & Menkveld, 2011). In recent developments, new specialised trading algorithms have been adapted with the ability to scan news headlines and

execute trades accordingly (Financial Times, 2007). The next evolution in AT was the ability to programme algorithms to assign sentiment to news stories. Trade would then occur according to this sentiment parameter. Buying stocks thereafter would take place in accordance to a "good news" sentiment story, while a "bad news" sentiment story would precipitate a sell/short of stocks (Securities Technology Monitor, 2009). Each evolutionary step of AT is reducing the influence of human traders in the decision-making process and in the trading environment.

Aldridge (2013) illustrates how the adoption of electronic trading has grown over the past decade: "adoption of electronic trading has grown from 25% of trading volume in 2001 to 85% in 2008" (p. 9). Hendershott et al. (2011) states that in 2009, 73% of the trading volume in the US markets was due to AT. However the growth and use of AT appears to have hit a saturation point. The New York Times (2013) states that "profits from high-speed trading in American stocks are on track to be, at most, $1.25 billion this year, down 35% from last year and 74% lower than the peak of about $4.9 billion in 2009."

Lin (2013) highlights examples of emerging implications and consequences of AT use. In terms of systemic risk to the financial markets, Lin (2013) discusses the issue of speed and connectivity. The velocity at which AT is able to execute trade decisions essentially makes the changes too rapid to record. A press realise from the Knight Capital Group Knight (2012) explains how the company lost approximately $440 million due an erroneous trade implemented by a trader via an AT platform. Once the order was confirmed, the speed of execution made it virtually impossible to stop or reverse. The flash crash of 2010, when a typing error instructed an algorithm to sell $4.1 billion of futures contracts, shows another example of how AT operation occurs too quickly to recall or rescind In 20 minutes the algorithm offloaded 75,000 contracts onto the market, even automatically accelerating its selling as prices plunged, New York Times (2010). Kirilenko, Kyle, Samadi and Tuzun (2011) reported that while AT did not trigger the flash crash, it did greatly exacerbate the market decline and volatility of the market.

The South African stock exchange, the Johannesburg Stock Exchange (JSE), has been in operation for over 125 years (JSE Limited, 2013d) and has seen an evolution of its market structure in the last 20 years. Each evolution has brought about greater automation to the market structure. The open outcry system was replaced by the Johannesburg Equities Trading (JET) system in 1997 (JSE Limited, 2013a). The beginning of the 21st century saw the market structure undergo various revolutions but each time the trading and matching engine remained at the London Stock Exchange (LSE). In 2012, with the implementation of a new equity trading platform - the Millennium Exchange trading platform - resulted in the trading and matching engine migrating back to the JSE from the LSE (JSE Limited, 2012). This change in market structure led to greater execution speeds; lower latency; greater executed trades; and volume traded (JSE Limited, 2013b).

The final step in the evolution of the JSE market structure will take place in the first half of 2014(JSE Limited, 2011b). The introduction of co-location facilities will bring the JSE into line with other developed stock markets. This increased automation of trading, according to Jain (2005), lowers cost of equity for listed firms due to improvements in liquidity and transparency in information of stock markets.

The ability of a stock exchange to promote a liquid market is due to its market structure and regulations. In 2011 the JSE was voted by the World Economic Forum as the best regulated exchange in the world (JSE Limited, 2011b). Cumming, Johan and Li (2011) conclude that stock exchanges which are well regulated exhibit higher trading activity, decreased volatility and increased liquidity.
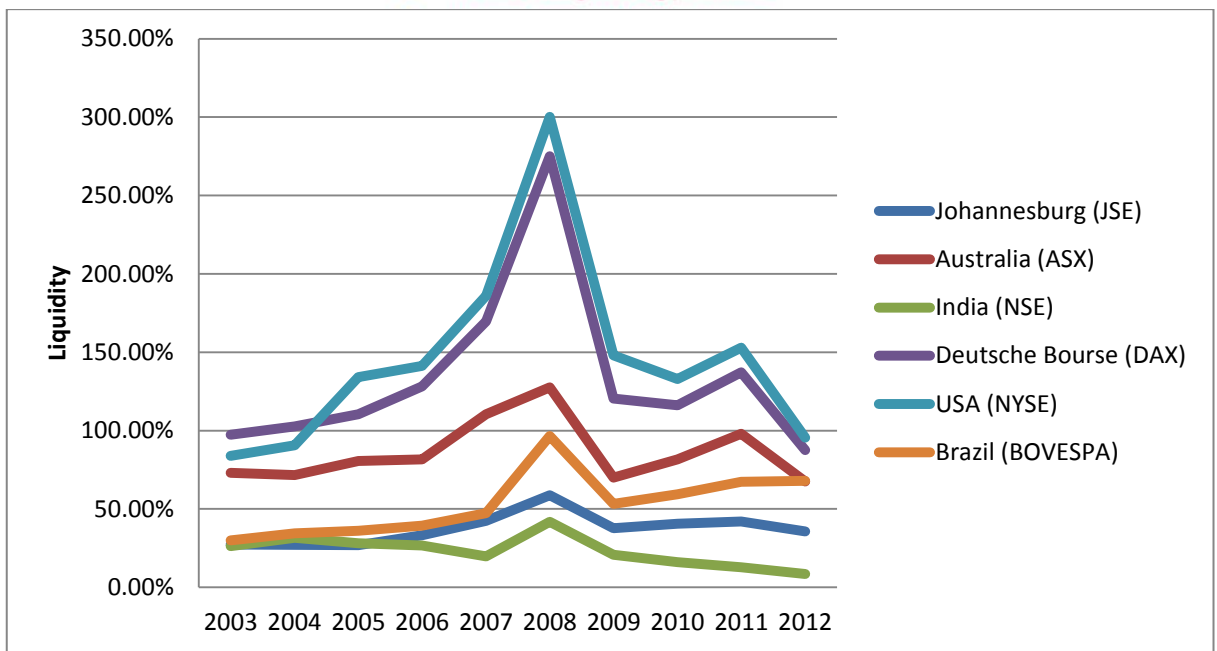
Figure 1: Comparison of World Stock Exchange Liquidity (Source: World Federation of Exchanges (2013), www.world-exchanges.org/statistics.

Figure 1 illustrates liquidity levels of various global stock exchanges. In comparison to other global markets the JSE is relatively illiquid. The JSE has turned over (volume traded), on average, 37.2% of its market capitalisation over the past decade. This is in comparison to developed markets such as the Australian Stock Market (ASX); German stock market (DAX); and a US stock market (NYSE); which turned over, on average, 86.2% (ASX), 134.5% (DAX) and 146.6% (NYSE) of their respective market capitalisation over the past 10 year period. Fellow developing markets also exhibit low liquidity: Over the past ten year period, the Indian stock market (NSE) turned over, on average, 23.3% of its market capitalisation, while Brazil's stock market (BOVESPA) turned 53.2%.

Gobodo (2007) cites the major reasons affecting the level of liquidity of the JSE as:

- the concentration of the South African equity market
- the concentration in the number of South African institutional money managers
- the departure of South Africa's largest companies to seek primary listings offshore
- the greater participation on the JSE by foreign investors

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AT, JSE market structure, and liquidity cannot be viewed in isolation, but must rather be viewed as factors that contribute the health of the trading environment in South Africa.

1.2 Research Problem and Purpose

This study investigates whether or not AT affects the liquidity of the JSE. Different low frequency liquidity measures were analysed in order to understand if and how AT affects liquidity. An internationally accepted AT proxy was employed in the study to measure the level of AT activity in the JSE. An exogenous event would allow the opportunity to investigate the relationship between AT and liquidity. Thus, in order to measure the effects of AT on liquidity, a time period was needed whereby an exogenous event occurred in the trading environment, which altered the market structure of the JSE. The introduction and implementation of the Millennium Exchange trading platform on 2 July 2012 was such an event.

The majority of previous studies have focused on developed markets such as Germany's stock exchange, DAX (Hendershott & Ricordan, 2011) , the Dutch stock exchange, AEX (Jovanovic & Menkveld, 2011) and the US stock exchanges, Nasdaq and NYSE (Hendershott et al., 2011;Brogaard, 2010). More recently, attempts have been made to investigate the international evidence of AT. One such attempt is Boehmer, Fong and Wu (2012). The study incorporates 39 exchanges which include both developed and emerging exchanges. The JSE was dropped from the final analysis due to the unavailability of high frequency data.

The MSCI has classified the JSE as an emerging market (MSCI, 2013), which presents an opportunity to broaden the theory of how liquidity is affect by AT in emerging markets. This will led to a better understanding of the difference in AT activity and liquidity levels between developed and emerging markets.

Previous studies have examined how AT affects the liquidity of a developed market (Hendershott et al., 2011). In terms of studies pertaining to the liquidity of the JSE, Hearn and Piesse (2009) investigated the effectiveness of certain liquidity measures

while measuring illiquidity within a multifactor CAPM pricing model. Bailey and Gilbert (2007) investigated the impact of liquidity on mean reversion of shares returns of the JSE. Reisinger (2012) investigates the effect of liquidity on stock returns on the JSE. However, according to the authors' knowledge, there has been no previous study which examines both the level of AT activity on the JSE and whether AT activity affects the level of liquidity on the JSE. In order to investigate whether AT affects the liquidity of the JSE five hypotheses have been proposed. The first hypothesis is supported or rejected by observing whether or not implementation of the Millennium Exchange trading platform contributed to a change in AT activity. The remaining four hypotheses are supported or rejected based on whether AT is significantly related to specific liquidity measures.

This research paper will investigate the relationship between AT and stock market liquidity. AT will be measured and be based on an AT proxy as proposed by Hendershott et al. (2011).

The study will then examine stock market liquidity through four liquidity measures. The first liquidity measure is the proportional bid–ask spread measure. This measurement is focused on the bid-ask spread, which is also able to measure the effect of transaction costs. The second measure of liquidity is the price impact measure of Amihud. This measurement is focused on how the price of a share is affected by order flow (large buy and sell orders). The third liquidity measure is of the stock turnover ratio which is focused on the volume of trade of a particular share in comparison to its shares outstanding share capital. The last measure of liquidity is the zero return measure. This measurement is focused on the return of a particular stock and trading activity. Only the top forty JSE listed shares for the period under review were considered as part of this study.

By examining the implementation of the Millennium Exchange trading platform there is an expectation of increased AT activity and duly increase liquidity. However, it is prudent to observe any change in market quality factors such as trade size and volatility.

1.3 Research Motivation

From an academic point of view, this study aims to extend current literature on AT and liquidity. Firstly this study is the first attempt to examine AT activity within the context of the JSE. By analysing AT activity around the time of the implementation of the Millennium Exchange trading platform, this study also contributes to the literature pertaining to the effects of AT on changes in market microstructure. This study will provide data which will prove valuable when comparing the level of AT activity on the JSE as compared to other developed, or any emerging markets.

Secondly the study will investigate whether or not AT impacts the liquidity of the JSE. The study will examine how AT affects different components of liquidity. In order to measure liquidity and its different components in an emerging market, four specific low frequency liquidity measures were selected based on the recommendations of Lesmond (2005).

From a non-academic standpoint, the study will highlight the uptake and prevalence of AT use by financial institutions and financial professionals in South Africa. This study will provide the JSE with a better understanding of the consequences of AT, particularity in reference to market quality factors such as average trade size and volatility. In the future, results in this study could be employed in guiding the JSE in terms of changing trading rules and regulations, as well as in the trading cost structure. Results of the study could influence traders and pension fund manager to alter their trading strategies in order to leverage off AT positive externalities. Regulators could see the need to tighten regulation pertaining to AT use in order prevent flash crash situations.

2. Literature Review

2.1 Introduction

The following literature addresses the importance, definition, and properties of liquidity. The implications of liquidity are then examined, and finally theory is presented with particular focus on a market microstructure approach to liquidity. Literature pertaining to the definition and use of trading algorithms are discussed, as well as looking at the main operators of the trading algorithms. Recent relevant theoretical and empirical evidence pertaining to the AT effect on liquidity, market quality and traders' welfare is also discussed. Emerging markets are briefly discussed, as the study is focused on the JSE, which is categorised as an emerging market. It is also important to understand how a study of the relationship between AT and liquidity in the JSE may be different to previous studies in developed markets, therefore an explanation will be provided.

2.2 Liquidity

Liquidity can be seen as the vital lubricant in trade that allows financial mechanisms and markets to function effectively. In the following literature the importance, definition, properties and implication of liquidity are discussed. A market microstructure approach to liquidity is discussed in terms of its foundational role in AT.

2.2.1 Importance of liquidity

Liquidity is a key fundamental lever required by any financial exchange. Liquidity has important consequences for traders, financial exchanges, and listed entities. More importantly, the stability of the financial ecosystem benefits from liquidity.

Liquidity forms a vital part in determining the rate of returns of assets. In recent years, Acharya and Pedersen (2005) have developed a liquidity adjusted capital asset pricing model (CAPM). In their findings, they state that investors demand a premium of less liquid stocks and therefore it is to be expected that future returns are negatively related to levels of liquidity. Therefore liquidity forms a vital part in determining rate of return of assets.

Brunnermeier (2009) illustrated the fundamental importance of liquidity or lack thereof which led to the financial crises of 2007-2008. The author explained how, through the interaction of funding liquidity and market liquidity, there was a sudden evaporation of liquidity in the market. Brunnermeier (2009) described how the loss spiral affects the margin/haircut spiral, which in turn amplifies the Borrower's Balance Sheet Effect. This decreases the liquidity level in the market place.

2.2.2 Definition of Liquidity

Liquidity is an elusive concept and is without a commonly-accepted definition. Many authors have tried to create an all-encompassing definition for liquidity, but the problem lies in the multidimensional nature of liquidity, as emphasised in Amihud and Mendelsohn (1986), Grossman and Miller (1988) and Kugler and Stephen (1997).

Liquidity is a measure of both the cost and ease with which an asset can be sold (Bodie, Kane & Marcus, 2011). A definition of liquidity from Pastor and Stambaugh (2003) confirms that of Bodie et al. (2011) who define liquidity as the ability to trade large quantities (of securities) quickly, at a low cost and without moving the price. The author intends to use the Bodie et al. (2011) definition of liquidity for the purpose of this study.

2.2.3 Properties of liquidity

The advantage of having a simple definition as mentioned above is counteracted by the difficulty of implementation, in the analysis of liquidity. In order to make the definition more specific, Black (1971), O'Hara (1995), Kluger and Stephan (1997) and Ranaldo (2001) identify several dimensions of liquidity:

1. <u>Trading Time / Immediacy</u> is characterised by the ability to execute trades of any size immediately. (Measured by the <u>stock turnover ratio</u>)

2. <u>Tightness/Width</u> is characterised by the ability to buy and sell an asset at roughly the same price in the same time period. Tightness illustrates the cost associated with the cost of Immediacy. Therefore the measurement of tightness is considered to be a different version of the <u>bid-offer spread</u>.

3. <u>Depth</u> is characterised by the ability to buy or sell a certain amount of an asset without influencing the price. (Measured by the <u>price impact measure</u>)

4. <u>Resiliency</u> is characterised by the ability to buy or sell an asset with as little influence as possible on the price. Alternately it can be viewed by how fast prices revert to previous levels in response to a large order flow. (Measure by the <u>price impact measure</u>)

It is understood that the different dimensions of liquidity do not stand independently, but can interact with one another. For example, a trader who is patient and does not demand immediacy, can obtain better prices and is able to trade larger amounts at the quoted price. In this example depth and resiliency depend on immediacy.
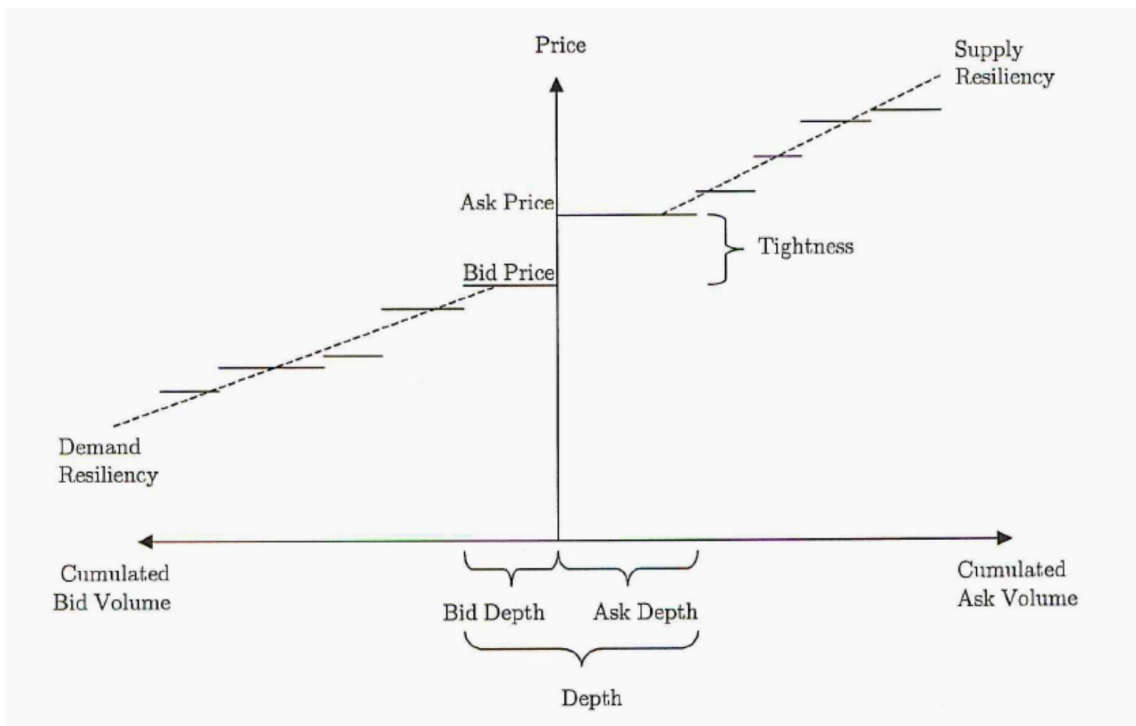
Figure 2: Different aspects of liquidity in a static image of the limit order book. (Source: Von Wyss , 2004)

Figure 2 illustrates an image of the limit, or book. The bid and ask volumes are illustrated on the horizontal axis. The volumes present at the bid and ask may differ but the sum of these volumes represent the measure for market depth. The price of the share is displayed on the vertical axis. The measure of tightness lies in the differences between the ask price, at which shares are offered, and the bid price, at

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which shares are demanded. . The resiliency dimension is captured by the supply and demand curve.

2.2.4 Implications of liquidity

Voster (2008) cited the following stakeholders and their interest in liquidity:

2.2.4.1 Government

Amihud & Mendelson (1991) highlighted governments' ability to influence liquidity via regulation and taxes. Investors seek liquid markets to in which to invest. Governments, therefore, must be cognisant of any negative effects of taxes and regulation on market liquidity.

2.2.4.2 Corporations

Amihud & Mendelson (1991) described that the increase in liquidity gained by a company when it lists on the stock exchange must be greater than the cost of listing. If the gain in liquidity is greater than cost of the listing, the director should list the company. A corporation's cost of capital is directly linked to its liquidity, which is another reason to list the company, and take advantage of lowering its cost of capital.

2.2.4.3 Investors

Amihud & Mendelson (1991) explained how securities which are relatively illiquid when compared to other securities compel investors to extend their investment horizon. This extended investment horizon is required due to the high transaction costs involved in dealing in an illiquid security.

2.2.4.4 Stock Exchanges and Regulators

Amihud & Mendelson (1991) stated that stock exchanges and regulators are able to positively or negatively affect the liquidity of a market. This can be achieved via trading costs; trading regulation; technology; and information dissemination. The main aim of stock exchanges and regulators should be to lower the liquidity premiums by employing the correct measures stated above.

2.2.4.5 Financial Intermediaries and Financial Engineering

Amihud & Mendelson (1991) illustrate that one of the primary roles of a financial intermediary is to increase the liquidity of an asset. As an example of this, the process of securitisation generates value by transforming illiquid claims (such as mortgages, auto loans) into more liquid claims.

2.2.5 Market Microstructure Approach to Liquidity

The nature of market's microstructure is capable of positively or negatively affecting the levels of liquidity of stock. It would be prudent to discuss literature from a market microstructure perspective. The JSE is an order driven market: liquidity is provided by traders and unexecuted limit orders. Therefore, if the supply of limit orders declines it will result in a reduction of trade.

2.2.5.1 Bid-Ask Spread

The Bid-Ask spread exists for the following three reasons:

1. Inventory costs

2. Order handling and process costs

3. Asymmetric information

Inventory costs refer to the costs incurred by a market maker in the pricing determination of the bid as well as the offers (Amihud and Mendelson, 1980). Order handling and processing costs refer to the maintenance of a continuous market as well as to the related costs of matching and clearing orders (Roll 1984). Asymmetric information refers to decisions to trade or not trade, based on possessing private information other traders do not possess. Glosten and Milgrom (1985) discussed how the bid-ask spread can be influenced by asymmetric information.

In an order driven market there is no expectation or obligation for traders to provide liquidity or make a market. Theory related to the bid-ask spread in an order driven market was discussed in this research. Glosten (1994) demonstrated that an order-driven market had a positive effect on the bid-ask spread. This resulted from trading based on private information. Handa, Schawrtz and Tiwari (2003) developed a model based on an order driven market, in which the arrival of news; and the differences in

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investors share valuation; were not public information. The model concluded that the size of the spread is a function of differences of valuations and adverse selection all caused by the existence of asymmetric information.

2.2.5.2 Liquidity Supply and Demand in Order-Driven markets.

All dimensions of liquidity (immediacy, bid-ask spread, depth and resiliency) are influenced and determined by the interaction of limit and market orders in an order-driven market. Limit orders provide liquidity in contrast to market orders, which demand liquidity. Consequently the trader's choice of order will duly affect liquidity. Theoretical models, discussed below, were designed in order to understand this dynamic choice faced by trader.

Parlour (1998) developed a one tick dynamic model of a limit order market whereby traders choose between limit and market orders. Parlour's conclusion was that depth plays a pivotal role in the trader's determination of order type i.e. the traders considered the depth of the bid and ask before deciding on order type.

Foucault (1999) employed a theoretic model of price formation and order-placement decisions in a dynamic limit-order market. Foucault (1999) analysed execution risk with particular focus on analysing a trader's order placement strategy (mix of limit and market orders).This was done in an attempt to understand the risk that traders face in being picked off (the risk of a traders limit order being picked off/executed before the traders has the opportunity to cancel the order).

The volatility of the asset was the main determinant of the order-placement strategy (mix of limit and market orders). Consequently, the volatility of the asset increases as the likelihood of being picked off increases. This results in the widening of the spread as limit order traders require greater compensation for the increase in volatility (increased risk of being picked off). This increase in spread results in an increase in cost for market orders. This in turn favours limit orders as the optimal trading strategy.

Foucalt, Kadan and Kandel (2005) focused on another determinant of trader choice between limit and market order. They looked at this by using a dynamic model based on limit order market in which traders display different degrees of impatience: patient

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traders submit limit orders, while impatient traders place market orders. Foucalt et al. (2005) concluded that the resiliency of the limit order book increased in proportion to the trader's patience and the waiting cost, while it decreased the rate of the order arrival.

Below is a discussion on the extensive body of empirical literature which exists on this subject:

Biais, Hillion and Spatt (1995) analysed the limit order book and order flow of the Paris Bourse. Biais et al. (1995) concluded that the conditional probability on a limit order was larger than when the spread was large or the order book was thin i.e. the depth was low. This means that liquidity was supplied when it was valuable and consumed when abundant. Therefore, once a market order was placed, the likelihood the next order would supply liquidity was high. The results produced in the study indicate that traders should monitor the book and wait for profitable trades. Ahn, Bae and Chan (2001) performed a similar analysis on the Hong Kong Stock Exchange. Ahn et al. (2001) achieved the same results as Biais et al. (1995) whereby liquidity was provided when needed.

2.2.5.3 Resiliency

As discussed previously, Foucalt et al. (2005) illustrated that the resiliency of the order book increased in proportion to the trader's patience and the waiting cost and therefore, also decreased the order arrival rate.

DeGryse, de Jong, van Ravenswaaij and Wutys (2005) analysed the resiliency of a pure limit order market by studying the limit order book and transaction prices. The authors noticed that aggressive limit orders were placed when spreads and depths were low.

DeGryse et al. (2005) concluded that the price impact of an aggressive order was somewhat reversed by the following trades. Large (2007) performed a similar research whereby he investigated the resiliency of Barclay plc. (Listed on the LSE). Large (2007) reached a similar conclusion when he observed that aggressive limit orders were placed into the market following an aggressive market order. The purpose of the limit order was to replenish the liquidity that was consumed by the market order.

2.2.6 Other factors which affect liquidity.

Factors such as stock market design, infrastructure, policy and trading style all affect liquidity in different ways. The areas of liquidity which are affected are transparency, anonymity, tick size, trading floor vs. screen based trading systems and inter-market competition.

2.2.6.1 Transparency

Pagano and Roell (1996) defined transparency as the ability of stock market participants to observe information about the trading process. Transparency is further broken down into pre-trade transparency, which allows for market professionals to infer their competitors' order flow from their pricing (e.g. bid and ask prices as well as depth). Post-trade transparency refers to explicit information regarding recent trades (e.g. prices and trade sizes). Differing degrees of transparency (pre-trade and post-trade) will affect traders' strategies, and therefore liquidity. A high level of transparency will result in additional informative prices. However, the downside is that it could hinder liquidity as traders would not want to disclose their intention to the market. It must be highlighted that informed traders prefer less transparency while liquidity providers prefer more.

Pagano and Roell (1996) concluded that an increase in both pre- and post-transparency resulted in higher levels of liquidity. The implicit bid-ask spread narrowed due to price setters being better informed about the order flow. Price setters are better able to protect themselves against losses, allowing them to narrow the spread.

Boehmer, Saar and Yu (2005) investigated the consequences of making the NYSE limit order book public i.e. they studied the effect of greater pre-trade transparency. Boehmer et al. (2005) concluded that traders altered their trading strategies due to the order book being made public. Traders submitted smaller limit orders and cancelled orders more frequently and faster than before. In turn, this led to a decrease in the depth of the order book. It also contributed to trade shifting from the trading floor into further electronic trading. The increase in pre-trade transparency increased the informational efficiency of the market. This increase in liquidity was due to the decline in the price impact of trades and marketable trades. Boehmer et al. (2005) highlighted

that this rule change benefitted market order traders (liquidity demanders) but disadvantaged traders who submitted limit orders and market specialists (liquidity suppliers). The rule change adversely affected floor brokers' commissions since they executed trades less often.

2.2.6.2 Anonymity

The issue of anonymity in the context of the stock market can be defined as the identity of the market participants being revealed or not. Anonymity functions in the same way as transparency: liquidity traders prefer not to be anonymous, while informed traders prefer to remain anonymous

Foucalt, Moinas and Theissen (2006) analysed the effect anonymity has on liquidity and concluded the following: When liquidity demanders' information was concealed there was an increase in the spread due to the liquidity suppliers being unable to distinguish between informed and uninformed traders. However, when the identity of the suppliers of liquidity information was concealed, the size of the spreads was reduced and the market depth decreased. This was due to expert traders not being able to better assess the trading strategies of other traders in the market. Therefore they acted in a more aggressive manner, which resulted in spreads and depth declining.

2.2.6.3 Tick size

Tick size can be defined as the minimum price movement of a trading instrument i.e. the minimum price increment in which prices change. The change in the tick size propagated by change in regulations had profound consequences on market quality, as well as on liquidity.

Chordia and Ball (2001) and Goldstein and Kavajecz (2000) investigated the effect of a reduction of the minimum tick size. Both studies concluded that due to the reduction in the minimum tick size there was a decrease in the average spread size but in turn decreased the depth of both the bid and ask. Therefore, the gain in liquidity in the bid-ask spread dimension (tightness) was offset by the decrease in another liquidity dimension of depth.

2.2.6.4 Trading Floor vs. Screen based trading systems.

Different trading system types (trading floor vs. screen based) can affect the liquidity of a stock exchange.

Theissen (2002) examined the Frankfurt Stock Exchange which employed both a trading floor and a screen-based trading system. The results provided by his research illustrated that screen-based (electronic) trading system exhibited lower spreads for high liquid stocks. However, the trading floor trading system reduced the spread of less liquid stocks by more than the electronic trading systems.

Jain (2005) investigated the impact of automation (movement from the trading floor to electronic based trading system) of 120 exchanges around the world. Jain (2005) found that there was a significant reduction in equity premium, especially in emerging countries. More importantly with respect to liquidity, trading turnover increased, which enhanced the liquidity and the level of information of the stock exchanges. This in turn led to a reduction in the cost of capital i.e. automation led to the lowering of the cost of equity for listed firms.

2.2.6.5 Inter-Market Competition.

Inter-market competition must be analysed as a factor which could determine liquidity. This is due to shares being traded simultaneously on different exchanges. The ability to trade on multiple exchanges implies that a trader must take trading cost, execution speed and market design across trading venues into consideration before trading.

Parlour and Seppi (2003) examined if and how competition between traders could affect liquidity. The results demonstrated that the traders' welfare/profitability was increased due to a reduction in trading costs, which in turn improved liquidity as the bid-ask spread narrowed. However, the fragmentation of order flow between the two trading venues caused a decrease in liquidity.

Foucault and Menkveld (2008) investigated the competition between two limit-order books. The study focused on the entry of EuroSETS from LSE in the Dutch market (Euronext). The main finding was that competition improved the consolidated order

book depth. This was achieved due to competition between liquidity suppliers which forced trading venues to reduce their trading fees.

Colliard and Foucault (2012) studied the effect of trading fees on the efficiency of limit order driven markets. Collaird and Foucalt (2012) confirmed previous findings that competition between exchanges was more beneficial than no competition. Traders' welfare was increased due to a reduction in trading costs. However, the cost structure of make and take fees caused the bid-ask spreads to increase or decrease depending on the order type the trader employed. Limit orders are subject to lower trading fees, as this type of order supplies liquidity, whereas market orders require a higher trading fee, as they are seen to demand liquidity. Therefore traders prefer to submit limit orders, which increase the depth of the order-book. However, limit orders have a lower fill rate (execution rate) than market orders.

2.2.7 Liquidity measures

There are different varieties of liquidity measures. The type of liquidity measure is determined by which component of liquidity needs to be measured. The bid-ask spread measures investigate the tightness component of liquidity. High, or low frequency data also determines which liquidity measure can be employed. Low frequency liquidity measures were employed in this study. The reasoning behind which liquidity measures were employed is discussed in section 2.4.3 and again in chapter 4.

2.2.8 Summary of liquidity concepts

From the existing literature available, it becomes apparent that liquidity fulfils an important role in the financial and economic space. Implications of liquidity can be seen to affect multiple stakeholders and, as previously stated, it has the ability to affect every financial market around the word, which was seen in the 2007-2008 financial crises. Due to the multiple properties it possesses (immediacy, tightness, depth and resiliency) there is also no all-encompassing definition for liquidity.

The literature presented also demonstrates that the market microstructure of a stock exchange has the ability to directly affect the level of liquidity. Factors such as transparency; anonymity; tick size; trading systems; inter-market competition; and

cost structure; all influence the liquidity of a market. The factors of transparency, anonymity, trading systems and cost structure also play a role in promoting the use of AT.

2.3 Algorithmic Trading

Advancements in technology have led to a revolution in the way financial markets operate and the way in which financial assets are traded. Hendershott et al. (2011) state that:

> "Every step of the trading process, from order entry to trading venue to back office, is now highly automated, dramatically reducing the costs incurred by intermediaries. By reducing the frictions and costs of trading, technology has the potential to enable more efficient risk sharing, facilitate hedging, improve liquidity, and make prices more efficient. This could ultimately reduce firms' cost of capital." (p.1)

Combining this with the speed and quality of access to financial markets show that these factors encourage the use of algorithmic trading which is a remarkable example of technological innovation.

2.3.1 Definition, Reasons for Use and Operators of Algorithms

Hendershott et al. (2011) revealed that as much as 73% of the trading volume in the United States of America was generated by AT. JSE approximated that around 65% of all trading activity was generated by AT (JSE Limited, 2013c).

At this juncture a clear definition of AT is required. Domowitz and Yegerman (2005) define AT as the gradual accumulation or disposition of shares by institutions. Hendershott et al. (2011) extended the definition of AT to include all market participants who use algorithms to submit and cancel orders. There was a need to define high frequency trading (HFT) so as to distinguish between the two concepts. Chordia, Goyal, Lehmann & Saar (2013) cited the U.S.Commodity Futures Trading Commission (CFTC) definition for HFT as follows: a form of automated trading that employs "algorithms for decision making, order initiation, generation, routing, or execution, for each individual transaction without human direction" (Chordia et al.,

2013). Therefore AT can be seen to be any order entered onto an electronic platform whereby an algorithm executes according to pre-programmed trading instructions. HFT can be seen to be a special class or subset of AT. HFT is seen to employ proprietary trading strategies carried out by computers. The computers execute at high speeds (measured in milliseconds) to move in and out of positions, in an attempt to capture the profit offered by the size of the bid-ask spread. This view was supported by Boehmer et al. (2012) and Hendershott et al. (2011).

Hasbrouck and Saar (2013) explained the difference in definitions by dividing AT according to the type of algorithm employed: "agency" or "propriety". Agency algorithms are employed by buy side institutions. The use of the agency algorithm was primarily to minimise execution costs during the process of portfolio rebalancing. Propriety algorithms incorporate the algorithms utilized by HFT.
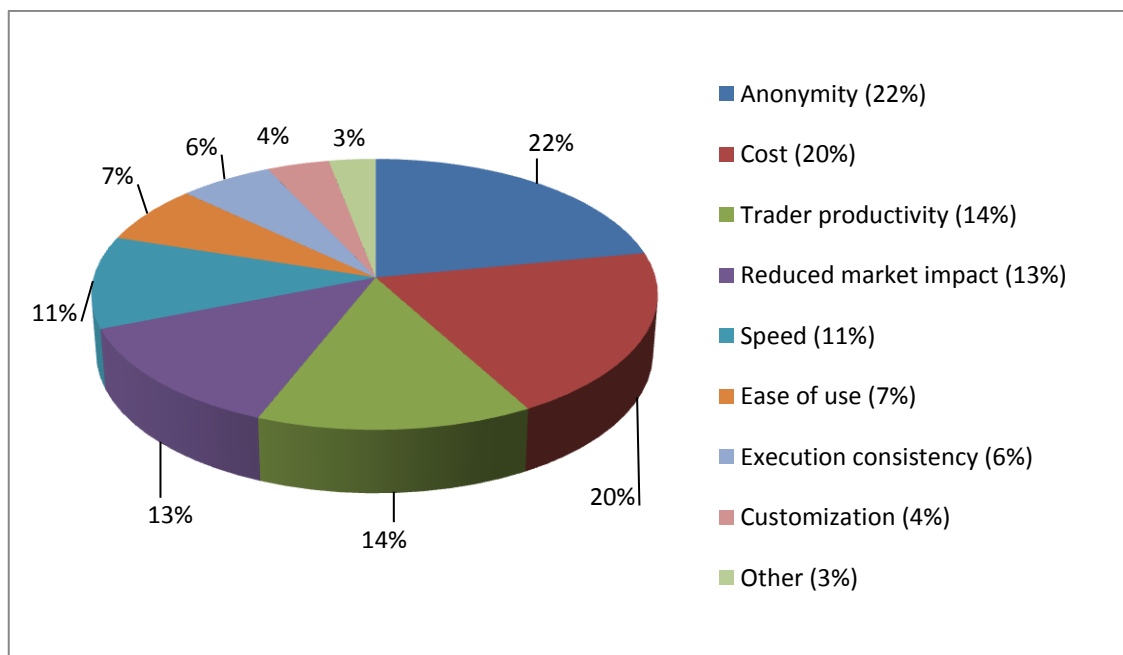
Figure 3: Reasons for Using Algorithmic Trading. (Source: Aldridge, 2013)

Aldridge (2013) cited the 2009 Annual Algorithmic Trading Survey, which emphasised the main reasons for the implementation of algorithms in trading, such as anonymity, cost savings, trader productivity and reduced market impact These reasons have been noted too by Financial managers and traders. Buy-side managers enjoy the positive externalities associated with AT via stealthy execution. Stealthy execution allows the institutional investors to hide their true intention for other traders, thereby reducing

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the market impact, cost and thus improving the profitability of the trade. The reduction of market impact, or price impact, was cited as one of the most important reasons for using AT. Leinweber (2007) explained that one of the first uses of AT was to split large orders into a smaller sized orders so as to mitigate the price-impact effect suffered when large orders were traded in the market. Due to the submission of smaller trades and higher frequency, AT was seen to have increased both the amount of messages and trades since early 2000 (Hendershott, et al., 2011). These two variables form part of the AT proxy used to measure AT activity. The AT proxy is discussed further in section 4.1.1.
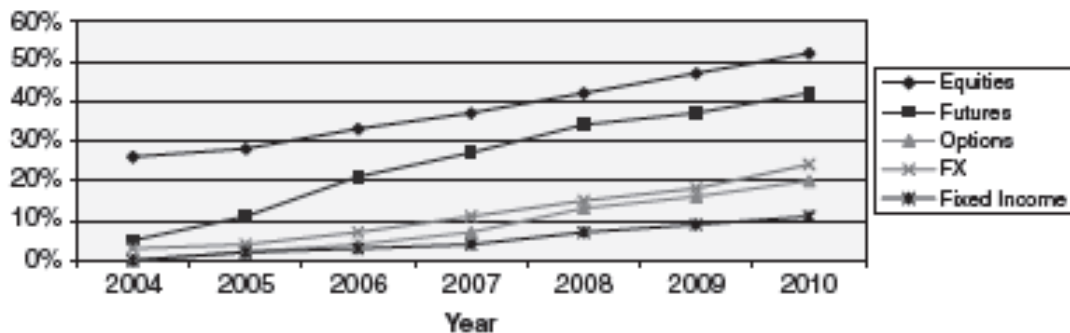
Figure 4: Adoption of Electronic Trading Capabilities by Asset Class (Source: Aldridge, 2013)

Aldridge (2013) cited research conducted by the Aite Group, which focuses on the adoption of algorithmic execution by asset class. By 2010 over 50% of equity volumes were traded by algorithms on US equity markets. The rise of the uptake was due to advances in technology, regulations changes and market microstructure, as cited by Aldridge (2013).

2.3.2 Theory and Empirical Evidence

2.3.2.1 Algorithmic Trading

Hendershott et al. (2011) investigated the empirical relationship between AT and liquidity. Due to the difficulty in obtaining AT specific data, Hendershott et al. (2011) constructed a normalized measure of NYSE electronic message traffic as a proxy for AT. This AT proxy was regressed against various bid-spread liquidity measures, as well as other stock market variables, in order to understand the relationship between AT and liquidity.

Hendershott et al. (2011) acknowledged that AT and liquidity can move in the same direction, and that it is possible that the relationship is not causal in nature. The implementation of auto-quoting on the NYSE in 2003 was a significant change to the NYSE market structure. Prior to 2003, specialists were required and responsible for manually distributing the inside quote (maintaining the best bid and ask prices in the order book). In 2003 this process was changed and a new automated quote system - "auto quote" - automatically updated the limit-order book. This was the exogenous event that was needed in order to study the growth of AT and liquidity. The reason for the inclusion of this exogenous event was to allow the author to differentiate between the growth of AT due to a change in market structure, and not due to the natural growth of the market. The change in growth of AT due to the event allowed the author to investigate the relationship between AT and liquidity.

Hendershott et al. (2011) investigated the effect of the implementation of an automated quoting system at the New York Stock Exchange (NYSE) in relation to the growth of AT and the improvements in market liquidity. The findings of the study illustrated the following: the amount of AT messages significantly increased after the exogenous event (assuming that AT was responsible for all messages generated). Liquidity was measured through various bid-ask spreads and price impact measurements. Surprisingly, for large cap shares, the effective and quoted spreads increase slightly. This was attributed to liquidity suppliers obtaining market power via their specialist ATs and therefore were able to influence the spread. This market power was temporary as the rest of the market participants invested in AT and liquidity suppliers lost their technological edge. Quoted and effective spreads were narrowed for mid and low cap shares. Price impact was reduced, however the quoted depth also decreased across all shares listed on the NYSE.

The narrowing of the spreads resulted in a decrease in adverse selection, or a greater efficiency in the price discovery process associated with trades. An increase in AT activity was seen to quicken the price discovery process that transpired without trading. This infers that price discovery took place via quotes rather than trades.

Boehmer et al. (2012) complemented the results of Hendershott et al. (2011). They did so by searching for international evidence on electronic messaging traffic and market quality across 39 exchanges (both developed and emerging markets) over the period 2001-2009. Boehmer et al. (2012) also employed the AT proxy developed by Hendershott et al. (2011) in order to track AT activity. Instead of using auto-quote as the exogenous variable, they investigated the offering of co-location facilities as the exogenous variable. Co-location allows for algorithmic traders and high frequency traders to locate their computer hardware as close as possible to the exchange's matching engine, thereby considerably reducing the electronic messages turnaround time. The reduction in latency provided by co-location was a change to the market structure and should be considered as an exogenous event.

Boehmer et al. (2012) concluded that the implementation of co-location facilities resulted in an increase of AT and HFT activity. This increase in activity resulted in improved liquidity in all stocks, expect for the low-capped stocks and high-volatility stocks. Informational efficiency significantly improved as a result, therefore confirming Hendershott et al. (2011) findings in terms of AT improving liquidity. However, contrasting results were reached when comparing large, medium and small caps.

Boehmer et al. (2012) noted that increased AT activity resulted in an increase in volatility. In terms of small stocks, AT was seen to reduce liquidity in this market segment. Finally, during trading days when market making was difficult, AT exacerbated the illiquidity situation and increased the volatility when compared to normal market making days.

Hendershott and Riordan (2011) investigated AT and the role it played in the price discovery process. The study focused in on 30 DAX stocks listed on the Deutsche Boerse. In this study, Hendershott and Riordan (2011) were able to obtain data pertaining to AT activity and therefore did not need to make use of an AT proxy in order to track AT activity. Hendershott and Riordan (2011) concluded that AT supplies liquidity when it is cheap and consumes it when it is expensive. AT contributes more to the price discovery process than human traders. The reason for this was that when a

price deviates from its fundamental value, AT would commence to place orders in the market and would drive the price up to an efficient price level. Importantly, AT was seen to not contribute to volatility beyond driving prices to more efficient levels.

Hendershott and Riordan (2012) examined the role played by AT in terms of liquidity supply and demand. In this study, the authors employed the same data set from their previous study in 2011 and did not need to employ an AT proxy. It must be noted that Hendershott and Riordan (2012) reaffirmed their previous findings that AT consumed liquidity when it was cheap i.e. the bid-ask spreads were relatively tight and would supply liquidity when it was expensive. This meant that the bid-ask spread was relatively wide but they went on to add that AT was likely reduce volatility in the process. Therefore, by AT providing a consistent level of liquidity, it may increase the market quality in the long term.

2.3.2.2 High Frequency Trading

Carrion (2013) examined HFT and other market quality impacts by using a sample of NASDAQ trades and quotes, which identified HFT activity. In the findings, HFT performed in the same way as AT in terms of supplying liquidity when it is scarce, and consuming it when it is plentiful. Additionally, the higher the rate of HFT participation in the market meant a greater level of information from order flow was reflected in prices. This reduced the adverse selection effect. Brogaard (2010) examined the impact of HFTs on the U.S Equity market. The examination entails analysing strategies utilized by HFTs and their relationship with market quality, with particular reference to volatility, price discovery and liquidity. Brogaard (2010) concluded that HFTs did not increase volatility but can possibly reduce it. HFTs do provide for more liquidity but it must be noted that HFTs contribute to the reduction of limit order-book depth. Lastly, HFTs are seen to enhance the price discovery process.

Hasbrouck and Saar (2013) examine the relationship between low latency activities and market quality. Low latency activities are defined as "as strategies that respond to market events in the millisecond environment" (Hasbrouck & Saar 2013). Therefore low latency activity refers to AT and that of HFT. Hasbrouck and Saar (2013) conclude

that an increase in low latency activity results in tighter quoted spreads; a reduction in the price impact effect; volatility in the short term decrease; and the depth of the limit order book increase. Therefore, liquidity and the market quality improves with an increase in AT and HFT.

2.3.2.3 Technological improvement effects

Riordan and Storkenmaier (2012) investigated the effects of technological upgrades on the market structure of a stock exchange, with a particular focus on the improvements in latency effects, market quality, liquidity and price discovery. The equity market under investigation was the Deutsche Boerse. On April 23, 2007 the Deutsche Boerse completed upgrades to its trading platform infrastructure, "the Xetra upgrade was designed to reduce the trading system latency from an average of 50 milliseconds to an average of 10milliseconds" (Riordan & Storkenmaier, 2012, p.421).

The reductions in latency resulted in a decrease in quoted and effective spreads, which in turn dramatically lowered the adverse selection costs. However, the ability to update quotes faster led to the position whereby liquidity suppliers were able to minimise losses to liquidity demanders. The reason for this was due to the superior price discovery environment created by lower latency i.e. higher rate of order quotes being placed and removed from the order book. Riordan and Storkenmaier (2012) reaffirmed the results of Hendershott et al. (2011) with regards to the winners take all aspect of the liquidity supplier (market power). The market maker who possesses the lowest latency line will be able to generate superior trading profits when the whole markets latency is reduced.

2.3.2.4 Trading costs

Foucault, Kadan and Kandel (2013) developed a model in order to explore the maker/taker pricing model (make and take fees) and to illustrate how this pricing model interacts with AT. The model provided insight in explaining this relationship.

Firstly make/take fees affected the rate at which market makers supply liquidity and market takers consume liquidity. In order to incentivise market makers to supply liquidity at a higher rate, the make fees must be reduced and the take fees increased. This effectively reduced the market makers' monitoring cost and increased the rate of

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supply of liquidity and decreases the rate at which market takers consume/demand liquidity.

The second insight shows how AT affects liquidity, volume and welfare. The model implied that there was a strong relationship between AT and the trading rate. For example, if a market taker monitoring cost was reduced it resulted in the market takers executing attractive market prices at a quicker rate, therefore increasing the trading rate. As liquidity was consumed at a higher rate it induced market makers to supply liquidity at a higher rate. This in turn resulted in an increase in the trading rate. Therefore, improving liquidity and volume traded and the trader's welfare. This increase comes from executing orders at a high rate and at better prices.

2.3.2.5 Volatility

Actions undertaken by AT and HFT in times of market stress (Flash crash of May 2006 and the financial crisis of 2007-2008) have been questionable due to the perceived negative effects AT and HFT have had on the quality of the market and its liquidity. Kirilenko et al. (2011) analysed HFT in the e-mini S&P 500 futures market on 6th May 2010 the day of the flash crash. Kirilenko et al. (2011) reported that HFT did not trigger the flash crash but greatly exacerbated the market decline and volatility. The reason for this was that HFT initially provided liquidity to absorb the selling pressure. However, the selling pressure soon overwhelmed the buyers and the HFTs began to aggressively liquidate their long positions and, which accelerated the price decline. Due to the excessive volatility experienced during the flash crash, HFT greatly reduced their trading rate, which in turn exacerbated the liquidity situation.

2.3.2.6 Summary of AT Theory and Empirical Evidence

From the existing literature it becomes apparent that increased automation increases market quality and liquidity. The introduction of financial institutions and markets makers who employ AT and HFT, as well as the adoption of new technology (low latency), narrows the bid-offer spread, which increases the liquidity. The introduction of co-location opportunities resulted in an increase in liquidity, and an increase in informational efficiency of prices. Fees and regulation are seen to influence AT's ability to provide liquidity depending on the trading cost structure (make and take fees) and

the strictness of the stock market regulations. However, AT behaviour during times of market stress is seen to exacerbate the situation by increasing the volatility and decreasing the liquidity.

2.4 Emerging Markets

The focus of the study pertains to the effect of AT on the liquidity of the JSE. Since the majority of the studies discussing the effects of AT on liquidity have taken place in developed markets there is a need to discuss and highlight the JSE history and market structure, as well as to present relevant theory on emerging markets and their differences to developed markets.

2.4.1 The History and Market Structure of the JSE

Due to the discovery of gold in 1886 on the Witwatersrand led to the establishment of numerous mining and financial houses. Their need to source capital led to the establishment of the JSE in 1887 (JSE Limited, 2013a).

On 7 June 1996, the open outcry trading floor was closed and replaced with an automated trading system known as the Johannesburg Equities Trading (JET) system (JSE Limited, 2013a). This improvement in the market structure caused the annual traded turnover to reach R117.4 billion (JSE Limited, 2013a). In 2002, the JET system was replaced by the London Stock Exchange's (LSE) SETS system (JSE Limited, 2013a).

The migration from an open- cry system to SETS and to TradElect resulted in an increase in trading volume (JSE Limited, 2011a). In 2007, a new trading platform was introduced: the JSE TradElect trading system. Like the SETS programme, the TradElect was licenced from the LSE, which meant that the trading matching engine remained in London.

In June 2012 the JSE converted to a new equity trading platform: the Millennium Exchange trading platform. This change resulted in the trading platform and trading matching engine being relocated to the JSE building in Johannesburg. This market structure change led to the execution of transactions being 400 times faster than the TradElect system (JSE Limited, 2012). Since the implementation of the new trading platform - Millennium Exchange - the number of trades is up by 57%; volumes by 4%;

and value of trades by 21% (JSE Limited, 2013b). As of August 2013, the domestic capitalisation of the JSE is R8.3 trillion (World Federation of Exchanges, 2013).

The final and latest upgrade to the JSE infrastructure will be the implementation of co-location facilities in the first half of 2014. This will place the JSE on par with other international exchanges in terms of infrastructure. The implementation of Co-location will offer 24 times faster access into the equity market, with a latency of 100 microseconds compared to 2400 microseconds. (JSE Limited, 2013c). International empirical studies by Boehmer et al. (2012) and Hendershott et al. (2011) suggest that the implementation of co-location facilities should result in increased AT and HFT activity. This should, in turn, improve the liquidity and informational efficiency of the JSE.

2.4.2 Determinants of Liquidity of Emerging Markets

According to Jain (2005), automation of the trading process has led to a lowering of the cost of equity for listed firms, due to improvements in liquidity and level of information of stock markets. The reduction is more noticeable in emerging markets than in developed markets.

Lesmond (2005) postulated that legal and political institutions have the ability to directly affect the market liquidity of a country. This was achieved through a reduction of political risk. Lesmond illustrated that the increase in political stability can lead to a drop in trading costs of 10 basis points, as well as a reduction in price impact of 1.7%.

Pillay, Muller and Ward (2010) cited the following reasons for the increase in liquidity of the JSE since 1984 as follows: liberalisation of securities dealing in 1995; introduction of an electronic trading system (STRATE) in 1999; the gradual relaxation of exchange controls; and the general improvement of the South African economy over the period.

Therefore a mixture of policy change, financial liberalisation, improvement in the market microstructure and general improvement of the economy have all influenced the level of liquidity of the JSE.

Krishnamurti, Šević,A and Šević, Ž. (2005) investigated the effects on firms from emerging markets which cross-listed their equity in international equity markets. Firms that cross list needed to improve their disclosure levels in accordance with the requirements of the international stock exchanges. The authors of the study concluded the following: that emerging firms which adhere to a higher quality of disclosure resulted in a reduction of the information premium which meant an increase in liquidity. A positive externality from this is the effect that is felt on the domestic market whereby the market quality has improved. This is due to the cross listed firm being in adherence with international disclosure regulations. Due to the cross listing, any mispricing in either market will led to arbitrage opportunities and will lead to an increase in trade, which will improve liquidity.

Cumming et al. (2011) investigated the relationship between stock market rules and regulations on market liquidity, as represented by velocity, volatility, and the bid-ask spread. The results imply that insider trading rules and market manipulation rules play a significant role in facilitating trading activity and decreasing volatility. Cumming et al. (2011) concluded that descriptive and detailed rules are positively related to velocity and negatively related to the bid-ask spread and volatility (increasing liquidity) .The inverse relationship exists for vague trading rules (increase in illiquidity).

Čekauskas, Gerasimovs,Liatukas, Putniņš (2012) studied the effect that market makers and stock analysts have in emerging markets. The author highlighted the results, which indicated that stock market quality was directly affected by the actions of market makers and stock analysts. The presence of stock analysts improved the information efficiency and the liquidity of the market, which was due to the increased access of information, which was generated by the analysts. The structure of market makers' agreements and compensation packages affected the quality of the market. Market makers have a positive effect on liquidity only when they enter into agreements with issuers and not the exchange.

Stock market micro structure; stock market regulation; market quality; and interactions of market participants all affect the liquidity of emerging stock markets.

2.4.3 Liquidity measures for emerging and other frontier markets

International studies carried out over the past decade have focused their energies on the stock markets of the Unites States (Nasdaq and S&P 500), United Kingdom (LSE) and mainland Europe (DAX, AEX and CAC). These markets are highly liquid, where low and high frequency data are easily available. Due to the growth of emerging markets and the potential growth of frontier markets, it has resulted in investors and researchers turning their attention to these markets. It must be noted that literature has been written, which focuses on the effect of liquidity within certain emerging markets. In spite of this, there is limited literature pertaining to the comparison of different liquidity proxies determining which are the most applicable and efficient in emerging markets.

Lesmond (2005) greatly contributed to understanding and measuring emerging market liquidity. He did so by trying to determine the efficacy of the most common measures of liquidity in estimating the underlying liquidity emerging markets. Four measures were tested against the quoted bid-ask spread. The measures of liquidity were: the stock turnover ratio and Amihud (2002) price impact measure; Rolls measure (Roll, 1984), which was employed to measure the effective spread and the Lesmond, Ogden and Trzcinka (LOT) measure. This measure was developed by Lesmond (1995) in order to measures a firm's liquidity by taking into account transaction costs.

Lesmond (2005) findings were as follows: liquidity costs vary across emerging markets from as little as 1% in Taiwan to Russia, at 47%. Results pertaining to South Africa were as follows: the liquidity cost in South Africa was around 6% which was low when compared to the other emerging countries. This signifies that South Africa was relatively liquid. Lesmond (2005) analysed the measures both on an international and national basis. Within country liquidity, the LOT measure and Amihud price impact measure were the best measures. Overall the LOT and Rolls measure were the best in cross country effects. In order to determine the efficacy of the measures within a country, three tests were performed: factor analysis, regression analysis and a likelihood ratio test. These test confirmed that LOT measure followed by the Amihud

price impact are the most effective measures of liquidity while the stock turnover ratio was the worst. In this study the following four liquidity measures were used:

1. Proportional Bid-Ask Spread
2. Stock Turnover Ratio
3. Amihud Price Impact ratio
4. Zero Return Measure

Bekaert, Harvey and Lundblad (2007) further examine the efficacy of liquidity measures across 19 emerging markets. Two liquidity measures were tested in the study: the zero return measure as well as a zero return interval measure, which incorporates the length of non-trading. The author's analysis revealed that the measures were positively correlated to the spread but negatively correlated to the turnover. Bekaert et al. (2007) also examined if the market liberalization process has had an effect on market returns and liquidity. The authors concluded that post-liberalization countries, which had integrated into the world economy, exhibited greater levels of liquidity. The reason cited being foreigners ability to invest in the newly integrated markets. Large portfolio (hot money) inflows and outflows is a characteristic that sets apart developing and developed markets.

In comparison to international research little has been undertaken in measuring the liquidity of South African market (JSE). De Villiers (1996) discussed the ways in which liquidity has been defined. He then expanded on the importance of liquidity. He went on to discuss various method of testing liquidity, and how to increase liquidity. The measures covered by this discussion were the bid-ask spread; liquidity ratio; volatility ratio; volume of trade; price elasticity; and time to optimal disposal. No empirical analysis was undertaken. The author concluded that liquidity was a multidimensional concept and it was not possible to measure with one measure. Additional research was suggested in order to uncover measures that could capture more dimensions of liquidity.

Hearn and Piesse (2009) were concerned with severe lack of liquidity of emerging markets, and how this lack of liquidity, combined with price rigidity, affects price

discovery process. The authors examined established liquidity estimators such as the bid-ask spread, Amihud price impact measure and the stock turnover ratio. The authors then compared the established measures with two new ratios: the proportion of daily zero returns measure and a new measure which focuses on the multidimensional nature of liquidity, such as the trading speed proposed by Liu (2006). The authors compare the effectiveness of the new measures against the more established measures. The results suggest that the multidimensional Liu (2006) measure and the zero returns measures are superior to the price impact measure of Amihud and the stock turnover ratio in capturing the price rigidity aspect of liquidity.

2.4.4 Summary of Emerging Market Context

The market structure of the JSE is not far behind that of developed markets. The trading and matching engine has been relocated back to the JSE. This has led to a reduction in latency speeds and vastly increased the limit at which messages may be submitted. The final market structure improvement needed is that of co-location, which will bring it in line with developed markets such the FTSE, NASDAQ and NYSE.

Another difference when comparing developed and developing markets is the availability of data and the levels of liquidity of the markets. These two factors play a pivotal role when it comes to measuring the liquidity of an emerging market. For example, the JSE does not store or disseminate high frequency data, which makes it impossible to calculate high frequency liquidity measures, and to compare these figures with developed market figures (a problem faced by Boehmer et al. (2012) which led to the JSE being dropped from the final analysis). Lack of liquidity and low trading activity increases the difficulty in choosing appropriate liquidity measure.

Market quality and interaction of market participants are factors which affect the liquidity of the JSE. Gobodo (2007) cited the following factors (Market quality and interaction of market participants factors) that affect the liquidity of the JSE: the concentration of our equity market; the concentration in the number of our institutional money managers; the departure of our largest companies to seek primary listings offshore; and the greater participation in our market by foreign investors "hot money". These factors affect the JSE's liquidity and market quality. These same factors

are prevalent in developing markets. Developed markets do not suffer from such deficiencies.

2.4.5 Summary and Conclusions to the Literature Review

The literature review was built on three pillars

- Liquidity concepts
- AT theory
- Emerging market context

Market structure plays an important role in AT activity as it creates an advantageous environment in which AT activity may flourish. AT activity is influenced by technological upgrades, rules and regulations, as well as trading fees and rebates.

In conclusion the literature illustrates why it is important to understand AT activity effect on liquidity. It also illustrates why liquidity is important and the most effective methods in measuring liquidity in an emerging market context.

No published South African study on AT could be found. Therefore it is hoped that this study will contribute to a better understanding of AT and its relationship with liquidity in the South African context.

3 Research Hypotheses

In line with the preceding literature review, the purpose of this research project is to investigate whether the launch of the equity trading platform - Millennium Exchange - on 2 July 2012 (JSE Limited, 2012) had a significant impact on trade in the JSE, and on the liquidity of stocks on the JSE. Additionally, the relationship between AT and liquidity is investigated.

This study aims to accept or reject the overall research question: Does AT affect the level of liquidity of trades in the JSE? The question will be answered by investigating the level of AT activity via an AT proxy. The AT proxy can be defined as:

AT Proxy = the number of trades per 1000 shares of volume traded.

The launch of the Millennium Exchange trading platform is regarded as an exogenous event, which caused a change in the market structure of the JSE. This change in market structure is used as an exogenous instrument in order to measure the relationship between AT and liquidity.

In order to ascertain if there is a relationship between the liquidity of the JSE and AT, the AT proxy will be examined in conjunction with various measures of liquidity. In an attempt to understand these effects, an AT proxy will be regressed against each of the liquidity measures.

The following hypotheses have been proposed:

3.1 Hypothesis 1

AT activity increases due to a change in the stock market microstructure, Hendershott et al. (2011) and Boehmer et al. (2012) postulate that AT activity increases in response to a change in the stock market microstructure. It is hypothesised that a change in stock market structure i.e. the implementation of the Millennium Exchange trading platform, will positively affect the level of AT activity.

H_1: AT = βQ + ε_1

Q is the Millennium Exchange trading platform dummy, set to 0 before the implementation, and to 1 afterwards. β denotes the slope.

It can also be hypothesised that this is a positive relationship, i.e. β is positive.

The null hypothesis states there is no significant positive increase in the level of the AT proxy (AT_B) in response to the implementation of the Millennium Exchange trading platform. The alternative hypothesis states that there is a significant positive increase in the level of the AT proxy (AT_A) since the implementation of the Millennium Exchange trading platform.

H_0: $AT_B > AT_A$

H_1: $AT_B \leq AT_A$

B= Before the implementation of the Millennium Exchange trading platform.

A= After the implementation of the Millennium Exchange trading platform.

3.2 Hypothesis 2

As explored by Hendershott et al. (2011) and Boehmer et al. (2012), AT activity will increase the liquidity of the market. It is hypothesised that AT significantly affects the Proportional Bid–Ask Spread (PSpread).

H_2: AT = βPSpread + ε_1

It can also be hypothesised that this is a negative relationship, i.e. β (the slope) is negative.

The null hypothesis states that there is no significant negative relationship between AT and the proportional bid-ask spread.

The alternative hypothesis states that there is a significant negative relationship between AT and the proportional bid-ask spread.

H_0:   β = 0

H_2:   β < 0

3.3 Hypothesis 3

AT activity will increase the liquidity of the market Hendershott et al. (2011) and Boehmer et al. (2012). It is hypothesised that AT significantly affects the Stock Turnover Ratio (STR)

H_3: AT = βSTR + ε_1

It can also be hypothesised that this is a positive relationship, i.e. β (the slope) is positive.

The null hypothesis states there is no significant positive relationship between AT and the stock turnover ratio (STR).

The alternative hypothesis states there is a significant positive relationship between the STR and AT.

H_0:   β = 0

H_3:   β > 0

3.4 Hypothesis 4

AT activity will increase the liquidity of the market Hendershott et al. (2011) and Boehmer et al. (2012). It is hypothesised that AT significantly affects the Amihud Illiquidity ratio/Price impact ratio (Pimpact)

H_4: AT = βPimpact+ $ε_1$

It can also be hypothesised that this is a negative relationship, i.e. β (the slope) is negative.

The null hypothesis states that there is no significant negative relationship between AT and the price impact ratio.

The alternative hypothesis states that there is a significant negative relationship between AT and the price impact ratio.

H_0:   β = 0

H_4:   β < 0

3.5 Hypothesis 5

AT activity will increase the liquidity of the market Hendershott et al. (2011) and Boehmer et al. (2012). It is hypothesised that AT significantly affects the Zero return measure (Zero)

H_5: AT = βZero+ $ε_1$

It can also be hypothesised that this is a positive relationship, i.e. β (the slope) is positive.

The null hypothesis states there is no significant positive relationship between AT and the zero return measure (Zero).

The alternative hypothesis states there is a significant positive relationship between AT and the zero return measure (Zero) due to AT activity.

H_0:   β = 0

H_5:   β > 0

4. Research Methodology

This study aimed to examine the effects of AT on the liquidity of the JSE. The study measured the level and effect of AT by constructing an AT proxy. The use of this proxy was in line with current literature (Hendershott et al., (2011);Boehmer et al., (2012)).In order to measure the effects on stock market liquidity, several liquidity measures were constructed in accordance with recent literature (Goyenko et al., 2009 and Lesmond 2005).

The data was of a quantitative nature, and consisted of secondary data information pertaining to JSE listed securities, for example share price, opening and closing prices, volume traded, number of trades and number of outstanding shares. A causal study was conducted, as the objective of the study was to understand the relationship between AT and that of liquidity of the JSE. (Zikmund et al., 2012). The study is longitudinal in nature as it tracks events over time, and was able to note the change (Saunders & Lewis, 2012)

In order to verify the accuracy, bias, and soundness of the secondary data, cross checks were performed using multiple data sources whenever possible (Zikmund et al., 2012). Bloomberg and I-Net Bridge were used to verify the accuracy of the data in the cross checking process.

The next section examines the AT proxy and various liquidity measures followed by the research designed employed. This is followed an analysis of the unit of analysis, population of relevance and the sampling method and size. Finally, the data collection process and data analysis approach is discussed.

4.1 AT Proxy and Liquidity measures

4.1.1 AT Proxy

The use of an AT proxy to capture AT was needed in this study as no data set exists which captures only AT generated messages and trades. Therefore, a suitable AT proxy needed to be constructed from the existing data set. Hendershott et al. *(2011)*

formulated the first known AT proxy. It was defined as the ***number of electronic messages per $100 of trading volume***.

By tracking the number of electronic messages, it was hoped to capture AT activity. Hendershott et al. (2011) highlighted the fact that without normalisation, the raw electronic message traffic measure captured only the increase in trade, and not the change in the nature of trading. Therefore, the normalised AT measure was employed, as it had the additional benefit of capturing changes in trading strategies. The AT proxy was also able to measure the "slice and dice" strategy, which is used by ATs and HFTs. This strategy allows for traders to trade the bid-ask spread by constantly being the first order in the order book for both the bid and offer.

The initial intention was to employ the AT proxy developed by Hendershott et al. (2011). In order to construct such a proxy, all messages submitted (new, modified and cancelled messages) to the JSE for the time period under investigation (2011/07/01 to 2013/06/28) was required. The data set received from the JSE was incomplete and did not include all the different types of messages. The reason behind this was that the JSE does not have the capability to capture and store all message data; therefore there is an incomplete data set. Preliminary testing was done using only the new message orders. However, on further investigation, it was found that new messages had remained constant for the two year period, and the AT proxy would not produce acceptable results. Therefore a new proxy needed to be constructed.

Hendershott et al. (2011) stated that their results were virtually the same when employing raw message traffic numbers, using the number of cancelled messages rather than the number of messages and number of trades as the AT proxy. Therefore it was decided to construct an AT proxy based on trades instead of messages. The AT proxy employed in this study is defined as:

The number of trades per 1000 shares of volume traded.

The new AT proxy was normalised in order to eliminate the effect of market conditions, as per Hendershott et al. (2011). This AT proxy was successful in capturing the "slice and dice" strategy, due to the proxy being based on number of trades as

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opposed to messages. The problem with this new proxy was that it was unable to measure the constant price discovery process employed by AT. The number of messages, instead of number of trades, would have been better suited to capture this process. This would have a significant effect on the study, as essentially the new proxy was unable to account for the price discovery process.

4.1.2 Liquidity Measures

Four measures of liquidity have been employed in this study. All four of these measures are low frequency measures. No high frequency measures were employed in the study due to lack of high frequency data. Goyenko et al. (2009) postulated that high frequency measures produce better quality measurements when compared to low frequency measures. The measures used are the proportional bid-ask spread, stock turnover ratio, price impact measure, and zero return measure.

Amihud and Mendelson (1986) introduced the bid-ask spread, which formed the basis of successive research on liquidity measures. Lesmond (2005) studied the liquidity of emerging markets and discovered that the Amihud (2002) price impact measure and the zero return measure were the most effective measures of liquidity on the South African market. The stock turnover measure performed the worst. The three measures - the price impact measure, the zero return measure, and the stock turnover measure - were incorporated into this study in order to investigate if the same results apply to the data set employed in this study.

According to Amihud (2002), it was doubtful that there was one single measure that could capture all aspects of liquidity. Therefore, in order to capture trading speed and trading frequency - which represents immediacy - the stock turnover was employed to capture this aspect of liquidity.

The price impact ratio tracked the price movement connected with trading volumes, or the price impact of the order flow. Therefore, stocks can be classified as illiquid if small trades cause high price movements. Alternatively, stocks are regarded as liquid if large trades cause small price movements.

Chai, Faff and Gharghori (2010) summarised how each liquidity proxy captured a different dimension of liquidity. Chai et al. (2010) indicate that

> "Proportional spread and the zero return measure can be categorised as measures of tightness since both proxies reflect trading costs. The illiquidity ratio represents the price movement associated with trading volume and therefore, it is related to depth/price impact. Finally, stock turnover represent immediacy because the proxy reflects trading speed and trading frequency." (p.184)

For the purpose of this study, liquidity measures were calculated on a weekly basis, instead of a monthly basis.

4.1.2.1 The proportional bid-ask spread

The proportional bid–ask spread for stock *i* in week *t* was given by:

$$ pspread_{i,t} = \frac{1}{D_{i,t}} \sum_{d=1}^{D_{i,t}} (p_{i,d,t}^{A} - p_{i,d,t}^{B}) / (0.5 p_{i,d,t}^{A} + 0.5 p_{i,d,t}^{B}) $$

where $p_{i,t}^{A}$ ($p_{i,t}^{B}$) was the daily close ask (bid) prices for stock *i* on day *d* in week *t*, and *D* was the number of daily observations for stock *i* in week *t*.

The proportional bid-ask spread was based on the quoted bid-ask spread introduced by Amihud and Mendelson (1986). It provides a direct measure of transaction costs. The proportional spread was employed as an estimation of an average round-trip transaction cost. A greater spread of the asset means a greater level of illiquidity. Therefore the spread was negatively related to liquidity. The proportional spread overcomes the problem of quoted spread being an increasing function of stock price.

Despite being a widely used measure of liquidity, several authors have noted its shortcomings. Gross and Miller (1988) noted that buying and selling do not appear simultaneously, but are randomly separated in time. Therefore, the transaction price may occur outside or within the bid and ask prices. The spread does not account for this.

4.1.2.2 Price impact measure

The price impact measure of Amihud (2002), or illiquidity ratio, was defined as the daily absolute return of stock, divided by its trading volume on that particular day (Amihud, 2002).

The weekly price impact ratio was obtained from the following equation:

$$Illiquid_{i,t} = \frac{1}{D_{i,t}} \sum_{d=1}^{D_{i,t}} |r_{i,d,t}| \, / \, v_{i,d,t}$$

Where $r_{i,d,t}$ was the absolute return for stock *I* on day *d* in week *t*, and $v_{i,d,t}$ was the rand trading volume in millions for stock *I* on day *d* in week *t*, and *D* is the number of daily observations for stock *I* in week *t*. This weekly price impact measure was the same as the weekly liquidity measure employed in Chuang and Lee (2010).

It must be noted that the most important advantage of the ratio was that it could be employed for days where no price changes occurred. Due to the illiquid nature of emerging markets, it could be expected to notice low volume or no trading days. Low volume trading days resulted in minimal price changes of shares, therefore the use of the price impact measure was suitable in its use of studying the liquidity of emerging markets. This fact was highlighted by Lesmond (2005), whereby the ratio was declared to be the best measure of price impact for the South African market. Goyenko et al. (2009) confirmed Lesmond's findings and stated that the illiquidity ratio accurately captured the price impact component of liquidity.

Parallel with other measures of liquidity, the illiquidity ratio exhibits some drawbacks. Gross and Miller (1988) noted that the illiquidity ratio was derived using average price changes and average trading volumes from the past. This resulted in the ratio being unable to explain how stock price was influenced by the arrival of a large trade. Secondly, the ratio was unable to determine whether the price fluctuation was the result of new information or a lack of liquidity.

4.2.2.3 Stock turnover ratio

Stock turnover is the ratio of the number of shares traded, to the number of shares outstanding:

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$$turnover_{i,t} = \frac{1}{D_{i,t}} \sum_{d=1}^{D_{i,t}} \frac{VOL_{i,d,t}}{shares_{i,d,t}}$$

where $VOL_{i,t}$ was the total trading volume for stock i in week t and *share* $_{i,d,t}$ was the number of shares outstanding for stock i in week t. The number of shares outstanding was collected on a weekly basis and the volume traded for each stock was collected daily.

By capturing trading frequency, the stock turnover ratio offers a valuable indication of liquidity. It is expected that the stock turnover ratio will be positivity related to stock turnover ratio, and therefore the higher the turnover of a specific share, the more liquid it is.

In accordance with the clientele effect asserted by Amihud and Mendelson (1986), assets with larger spreads have relatively longer holding periods. Therefore, turnover of an asset should be positively related to liquidity but negatively related to the bid-ask spread.

There are drawbacks to this ratio. Firstly, it is unable to capture the cost per trade (Chai et al., 2010). Secondly, the ratio can emit false positive results. The financial crisis of 2008 was a classic example of this, as it was a crisis of liquidity. Turnover increased during this period instead of decreasing. This would indicate an increase in liquidity (in terms of turnover). However, the period was indicative of low liquidity (in terms of bid-ask spread and price impact).

4.2.2.4 Zero Return Measure

The proportion of zero daily returns observed over the relevant month was calculated as:

$$zeros_{i,t} = \frac{zeroreturn_{i,t}}{tradingdays_{i,t}}$$

Where *zeroreturn* $_{i,t}$ was the number of zero daily return days for stock *i* in week *t,* and *trading days*$_{i,t}$ was the number of trading days for stock *I* in week *t.*

The zero return measure was developed by Lesmond, Ogden and Trzcinka (1999). The justification for the measure was that informed traders would only enter trades that derive a profit which was greater than the transaction cost. Therefore if the value of information does not offset the cost of the transaction, then the informed marginal trader would not trade. In turn, this resulted in there being no price movement/change from the previous day.

The advantage of this measure was the ease of calculation, as well as the ease of the data collection, as it only requires information on daily stock returns. Bekaert et al. (2007) discovered that the zero return measure was correlated to other liquidity measures across emerging markets. Thus, the zero return measure was suitable in the use of measuring the liquidity of shares traded on the JSE.

There are drawbacks associated with the measure. Bekaert et al. (2007) noted that daily zero returns may be caused by a lack of information flow. Secondly, smaller shares are inclined to have high levels of non-trading when compared to larger shares. Finally, the zero return measure is unable to represent the trading behaviour of stocks due to its inability to measure price fluctuations that occur during the day.

4.2 Research Design.

The research was based on analysing secondary data relating to JSE listed securities in order to identify the prevalence of AT, as well as the relationship between AT and liquidity.

In the first phase of the research, the relationship between AT activity, and the exogenous impact due to the implementation of the Millennium Exchange trading platform, was investigated.

In the second phase of the research, the relationship between AT and liquidity was investigated. Different components of liquidity were examined via four liquidity measures. These measures were the proportional bid-ask spread, stock turnover ratio, price impact measure, and the zero return measure.

Lastly, the relationship between AT and market quality was investigated. Average trade size and price volatility variables were selected as measures of market quality. None of the hypotheses in chapter 3 relate to this investigation. The relationship between AT and market quality was added to the study in order to provide further context with regards to AT behaviour.

Regression analysis was selected in order to statically test these relationships. A 90% confidence level was used in testing the hypotheses.

4.3 Unit of Analysis

The unit of analysis for the study was the share information for each company analysed.

4.4 Population of Relevance

The population of relevance for this study was all the companies that were included in the JSE Top 40 index between 2 July 2011 and 28 June 2013. The start and end date for the study was selected to reflect one year of trading before and after the implementation of the Millennium Exchange trading platform. Time restrictions forced the time period to be narrow, as sufficient time was needed to apply for data from the JSE as well as to collect data.

4.5 Sampling Method and Size.

The listed companies that encompass the population of relevance were identified using information from the FTSE/JSE Index Series – Quarterly Review documents of the JSE website (JSE Limited, 2013e).

The JSE ALSI comprises of approximately 260 listed securities, with the top 100 shares accounting for 96.2% of the market capitalisation of the JSE ALSI. Due to time constraints and the very low frequency of trades of the small and medium cap shares, this study focused only on the top 40 listed securities.

Table 1 illustrates a summary of all the securities included in the research report. It was acknowledged that the shares that make up the JSE Top 40 index changed during the period under review (2 July 2011 till 28 June 2013) therefore creating the possibility of survivorship bias.

In order to compensate for survivorship bias, all companies that were listed on the JSE Top 40 during the duration of the study were included in the dataset. This is irrespective of whether or not they fell out of the JSE Top 40 due to the quarterly rebalancing of the JSE Top 40 index.

Table 1: JSE Top 40 Index constitutes 2 July 2011 - 28 June 2013

Security Name	Ticker	Securty Name	Ticker	Securty Name	Ticker
British American Tobacco Plc	BTI	Impala Platinum Holdings Plc	IMP	Massmart Holdings Ltd	MSM
BHP Billiton Plc	BIL	Goldfields Ltd	GFI	Woolworths Holdings Ltd	WHL
SAB Miller Plc	SAB	Nedbank Group Ltd	NED	Truworths International Ltd	TRU
Anglo American Plc	AGL	Exxaro Resources Ltd	EXX	Assore Ltd	ASR
Sasol Ltd	SOL	Shoprite Holdings Ltd	SHP	Growthpoint Properties Ltd	GRT
MTN Group Ltd	MTN	Sanlam Ltd	SLM	INTU Properties Plc	ITU
Companie Fin Richmont	CFR	Remgro Ltd	REM	Mondi Ltd	MND
Kumba Iron Ore Ltd	KIO	Bidvest Ltd	BVT	Mondi Ltd	MNP
Standard Bank Group Ltd	SBK	Tiger Brands Ltd	TBS	African Bank Ltd	ABL
Naspers Ltd-N-	NPN	Aspen Pharmacare Ltd	APN	Imperial Holdings Ltd	IPL
Anglo American Platinum Ltd	AMS	Steinhoff International Ltd	SHF	Discovery Ltd	DSY
Vodacom Group Ltd	VOD	RMB Holdings Ltd	RMH	Lonmin Plc	LON
First RandGroup Ltd	FSR	Harmony Ltd	HAR	Reinet Inv Soc Anon	REI
Anglogold Ashanti Ltd	ANG	African Rainbow Minerals Ltd	ARI	Mediclinic Ltd	MDC
Barclays Africa Group Ltd	BGA	Investec Plc	INL	Life Healthcare Group Ltd	LHC
Old Mutal Plc	OML	Investec Ltd	INP	Mr.Price Group Ltd	MPC

4.6 Data Collection Process

4.6.1 Data Collection
The study employed publically available information and data.

Daily, weekly, and monthly data was obtained for the top 40 securities listed on the JSE over the 24 month period, 1 July 2011 to 28 June 2013. Share price data and other trading information for these companies were obtained from databases provided by Bloomberg, I-net Bridge, and the JSE.

The AT proxy and the various liquidity measures were calculated using historical stock market records provided by Bloomberg and I-Net Bridge.

Information pertaining to index revisions from 1 July 2011 to 28 June 2013 was obtained via the JSE website (JSE Limited, 2013e).

Due to the exclusive use of secondary data, there was no obligation to design a primary data collection instrument.

4.6.2 Pre-Testing
Any problems that arise out of the test phase can inform improvements for the actual research undertaken (Saunders & Lewis, 2012). Pre-testing was undertaken and led to the discovery of the unsuitability of the new order message data collected by the JSE. This in turn led to the unsuitability of the original AT proxy, which created a need for the construction of a more appropriate AT proxy for this study.

4.7 Data Analysis Approach
The data analysis approach of this study followed a similar approach undertaken by Hendershott et al. (2011) and Boehmer et al. (2012). Hendershott et al. (2011) employed regression analysis as the preferred data analysis approach. Hendershott et al. (2011) justified the use of regression analysis due to the lack of a suitable structural model which could have been employed. Hendershott et al. (2011) stated that they achieved the same results when employing an event study approach instead of a regression. In this study a regression analysis approach was undertaken.

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The first step undertaken in this study was to calculate the AT proxy as per section 4.1.1. All four liquidity measures (section 4.1.2) were then calculated.

The next step of the data analysis was to understand the relationship between the implementation of the Millennium Exchange trading platform and the AT proxy. This relationship was tested by regressing the AT proxy (as the dependent variable) against a dummy variable which represented the Millennium Exchange trading platform

$Ait = \alpha i + \beta Qit + \varepsilon it,$

A_{it} was the relevant dependent variable, for example, the AT proxy.
Q_{it} was the Millennium Exchange trading platform dummy; set to zero before the Millennium Exchange trading platform introduction, and to one after the introduction.
αi was the y intercept

The next step was to investigate the relationship between the AT proxy and the relevant liquidity measures. Hendershott et al. *(*2011) surmised that the best way to test for association between liquidity and AT is to regress various liquidity measures (*Lit*) on AT (*Ait*).

$Lit = \alpha i + \beta Ait + \varepsilon it,$

Lit was the relevant dependent variable, incorporating liquidity measures (proportional bid ask spread, price impact measure, stock turnover ratio, and the zero return measure).
A*it* was the relevant independent variable, the AT proxy.

In order to provide a comprehensive study on the effects of AT the relationship between AT and market quality factors, such as average trade size and volatility, were investigated. The relationship between these market quality factors and AT was tested using the regression.

A separate regression was run on each of the market quality factors.

$X_{it} = \alpha_i + \beta A_{it} + \varepsilon_{it}.$

X_{it} was the relevant dependent variable, average trade size or volatility

A_{it} was the relevant independent variable, AT proxy

α_i was the y intercept

4.8 Research limitations

The research undertaken had the following limitations:

AT Proxy. The difficulty in tracking orders placed by AT required a proxy for AT to be compiled. Assumptions made in the computation of the AT proxy could impact on the validity of the results (refer to section 4.1.1.) Mainly the inability to measure and account for the price discovery process (Hendershott et al., 2011).

Data constraint. The exogenous event (implementation of the Millennium Exchange trading platform) occurred on 2 July 2012. Due this event being fairly recent, it limited the timeline in which data could be collected. Initially, the AT proxy and all liquidity measures were based on a monthly basis. The problem was that there were only 24 data points on which to run the regression. So it was decided to convert the AT proxy and liquidity measures into weekly data points, therefore the regressions were based on 100 data points. Financial studies undertaken by Chuang and Lee (2010) and Yeyati, Schmukler and Horen (2008), follow a similar approach and break monthly data into weekly data. Parametric testing can be employed for the data set. Ideally a minimum of 5 years of data would have been preferential.

High frequency data could not be attained, therefore limiting the usefulness and use of certain liquidity measures. The difficulty and cost of acquiring high frequency data led to the use of low frequency liquidity measures. Goyenko et al.

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(2009) discussed the suitability of low frequency liquidity measures, but ultimately preferred high frequency liquidity measures which produce a better quality measurement.

Infrequent trading (thin trading) occurs when a limited number of buy or sell orders are submitted to the market. This results in a low amount of traded volume days. Zero volume days are an input for certain liquidity measures, thereby skewing results. In order to reduce the influence of infrequent trading, the author decided to focus on only the top 40 securities on the JSE.

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5. Results

In this chapter the results of the analysed data is reviewed. Please refer to Appendices A to I for a complete repository of all the statistical data. This chapter is split into three parts.

The first part of the chapter examines the effect that the implementation of the Millennium Exchange trading platform had on AT activity. This section is used to answer hypothesis 1. The second part of the chapter examines the effect of AT activity on liquidity, which is measured using four specific liquidity measures. The second part of the chapter is used to answer hypotheses 2 to 5. The last part of the chapter examines the effect that AT has had on the average trade size and volatility of the market. This section answers none of the above mention hypotheses but provides further insight into AT.

5.1 Descriptive statistics

Appendix A contains a brief summary of all the descriptive statistics pertaining to the variables employed in the regression analysis process.

5.2 Implementation of the Millennium Exchange trading platform and AT
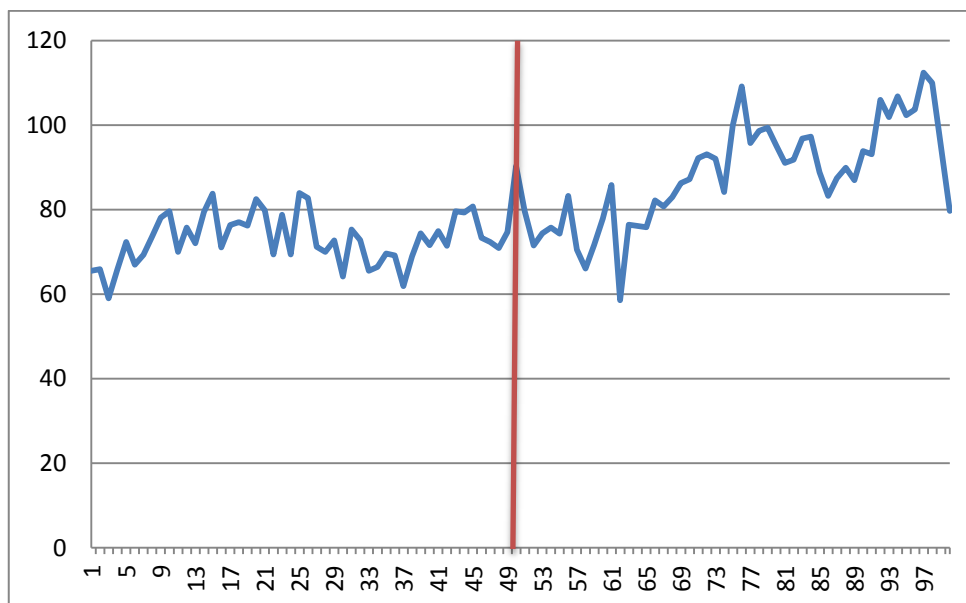
Figure 5: AT Proxy

Figure 5 is a graphical representation of the AT Proxy values for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There seem to be a positive relationship between AT activity and the implementation of the new trading system. There also seems to be a change in the AT Proxy slope post-implementation. This increase in the slope could represent a positive externality of the new trading system on the AT Proxy.

Prior to the implementation of the new trading system, the standard deviation was 6.25. Comparing the first 5 week period to the last 5 week period, prior to implementation of the new trading system, shows that AT grew 9.62%. In comparison, during the time period after the implementation of the new system, the standard deviation was 12.6. In comparing the first 5 week period to the last 5 week period post-implementation, AT grew by 24.05%.

Table 2: Summarised Results of Hypothesis 1

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F-Ratio	p-Value
Regression	1	5608.70	5608.70	59.92	< 0.0001
Residual	98	9172.50	93.60		
Total	99	14781.20			
R squared	0.38				

Significance of the model coefficients

	Dummy	Intercept
Coefficient	14.98	73.30
Standard Error	1.93	1.37
t-Value	7.74	53.57
p-Value	< 0.0001	< 0.0001

Correlation Matrix

	Dummy	AT Proxy
Dummy	1.00	0.62
AT Proxy	0.62	1.00

Table 2 is a summary of the results in Appendix B. From examining table 2, it can be deduced that the AT proxy and the dummy variable is positively correlated. Pallant (2010) determines the strength of the relationship to be strong, as the Pearson correlation coefficient of 0.62 is greater than 0.5.

Weiers (2010) describes the R squared as being how much of the variance in the dependent variable is explained by the model. Therefore, the model depicted in the table above explains 38% of the variability of the AT Proxy.

Due to the p-value being < 0.0001, which is less than the critical value of 0.1, we can reject the null hypothesis and accept the alternative hypothesis. Therefore, due to the implementation of the Millennium Exchange trading platform, a positive relationship exists between AT activity and a change in the stock market micro-structure.

5.3 AT Activity and Liquidity

5.3.1 Correlation between liquidity measures

5.3.2 The proportional bid-ask spread and AT
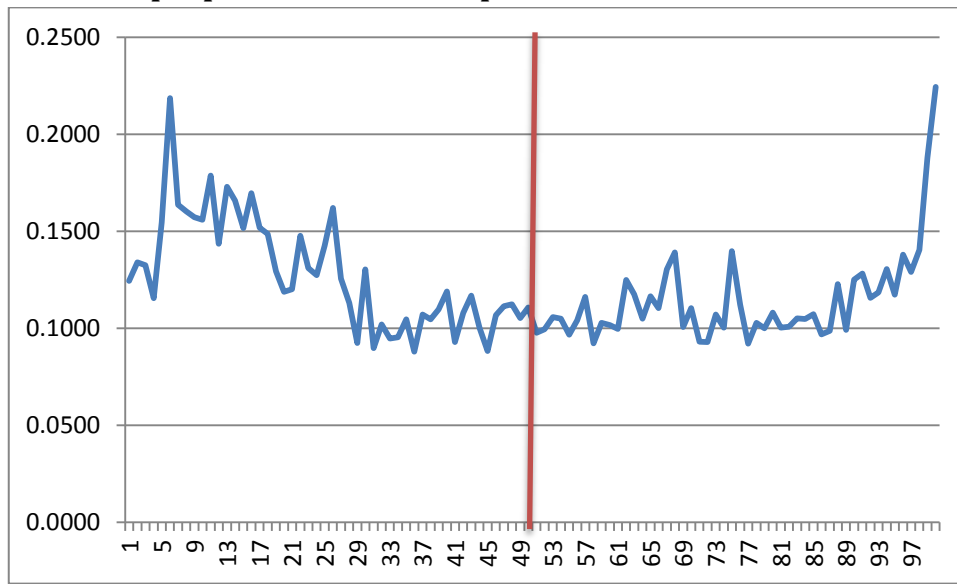
Figure 6: Proportional Bid-Ask Spread

Figure 6 is a graphical representation of the proportional bid-ask spread values for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There

seem to be a negative relationship between the proportional bid-ask spread and the old trading system. However, this relationship changes after to the implementation of the new trading system. This new relationship seem to be slightly positive in nature but this is more likely due to the sudden spike in the measure for the last trading week. The slope of the graph changes direction from a downward angle to a more sideways movement. This change in direction could represent that the implementation of the new trading system had no effect on the proportional bid-ask spread.

Prior to the implementation of the new trading system, the standard deviation was 0.028. During this period, the proportional bid-ask spread appears to be in a declining phase. After the implementation of the new trading system, the standard deviation was 0.023, which is less than the prior period. The proportional bid-ask spread appears to be constant over the period, except for the large uptick in the last week of trade.
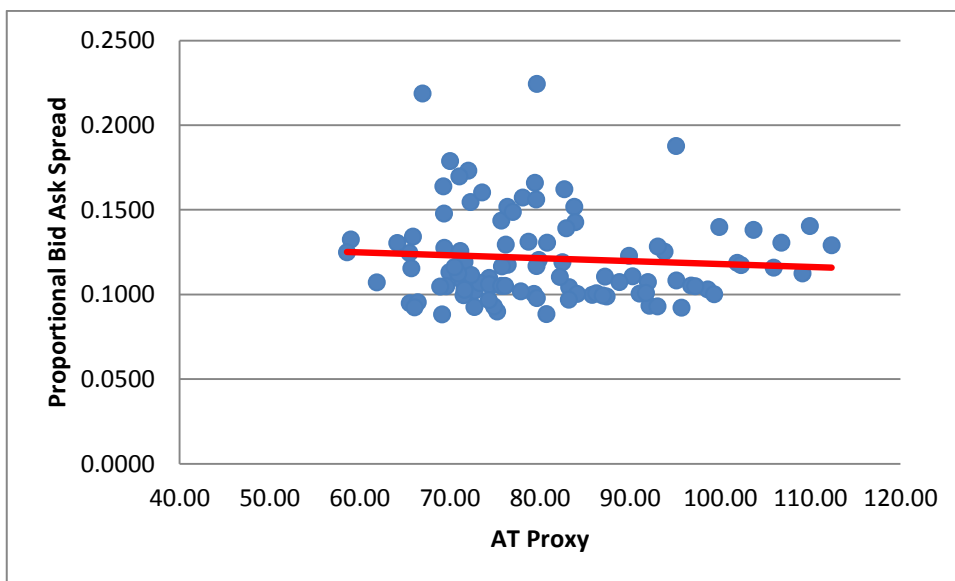
Figure 7: Scatter plot- Proportional Bid-Ask Spread vs. AT Proxy

Pallant (2010) proposes that scatter-plots are best used when exploring the relationship between variables. Scatter-plots are also able to provide an indication of the strength of the relationship. Pallant (2010) suggests constructing a scatter-plot before calculating a correlation matrix.

From figure 7, it can be inferred that there is a linear relationship which is negative in nature. The slightly downward sloping trend line signifies that there is a very weak

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negative relationship. A few outliers exist but the majority of the data points exist in a tight band surrounding the downward sloping trend line.

Table 3: Summarised Results of Hypothesis 2

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	0.0004378	0.0004378	0.60	0.439
Residual	98	0.0711697	0.0007262		
Total	99	0.0716075			
R squared	0.006114415				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	-0.000172108	0.1351346
Standard Error	0.000221656	0.0181089
t-Value	-0.7765	7.4623063
p-Value	0.4393	< 0.0001

Correlation Matrix

	Proportional bid-ask Spread	*AT Proxy*
Proportional bid-ask Spread	1.00	-0.078
AT Proxy	-0.078	1.00

Table 4 is a summary of the results in Appendix D. The proportional bid-ask spread and the AT proxy is negatively correlated. However, the strength of this relationship is very weak at -0.078.

The R squared of the model is exceptionally low at 0.6%. Therefore the model is able to explain only 0.6% of the variability of the dependent variable proportional bid-ask spread).

The p-value of 0.439 is greater than the critical value of 0.10, with a 90% level of significance; we cannot reject the null hypothesis. Therefore no significant relationship exists between the Proportional bid-ask spread and the AT Proxy.

5.2.3 Stock turnover ratio and AT
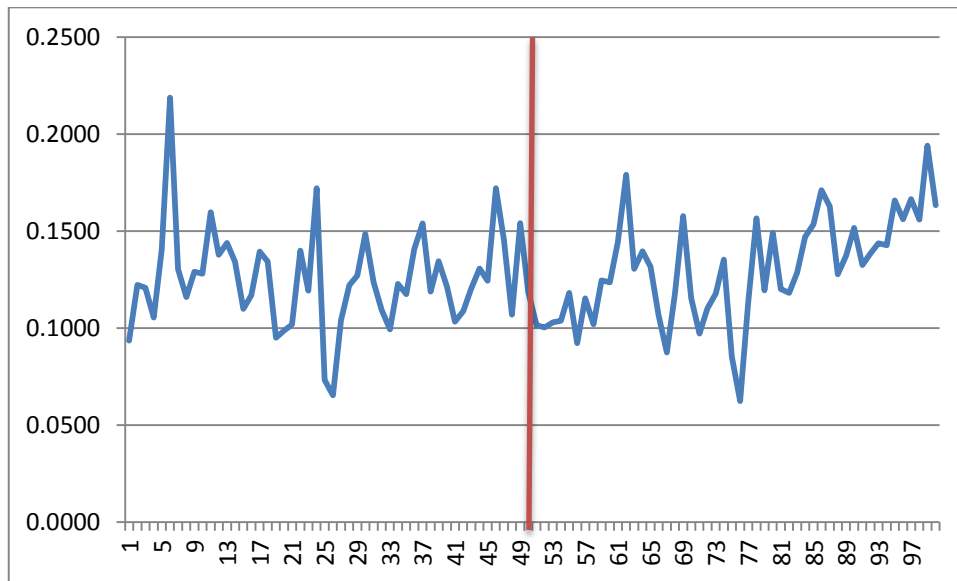
Figure 8: Stock Turnover Ratio

Figure 8 is a graphical representation of the stock turnover ratio values for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There seem to be a slight positive relationship between the stock turnover ratio and the implementation of the new trading system. There is a slight change in the slope of the graph following the implementation of the new trading system. This slight increase in the slope could represent a positive externality of the new trading system on the stock turnover ratio.

Prior to the implementation of the new trading system, the standard deviation was 0.0254. During this period the stock turnover ratio exhibited a slight upward trend. The stock turnover ratio increased by 26.83% for the period and by 0.55% per week. After the implementation of the new trading system, the standard deviation was 0.02695. The stock turnover ratio exhibits a strong upward trend, with a 61.03% increase during this period. This means that there is a 1.25% increase per week.
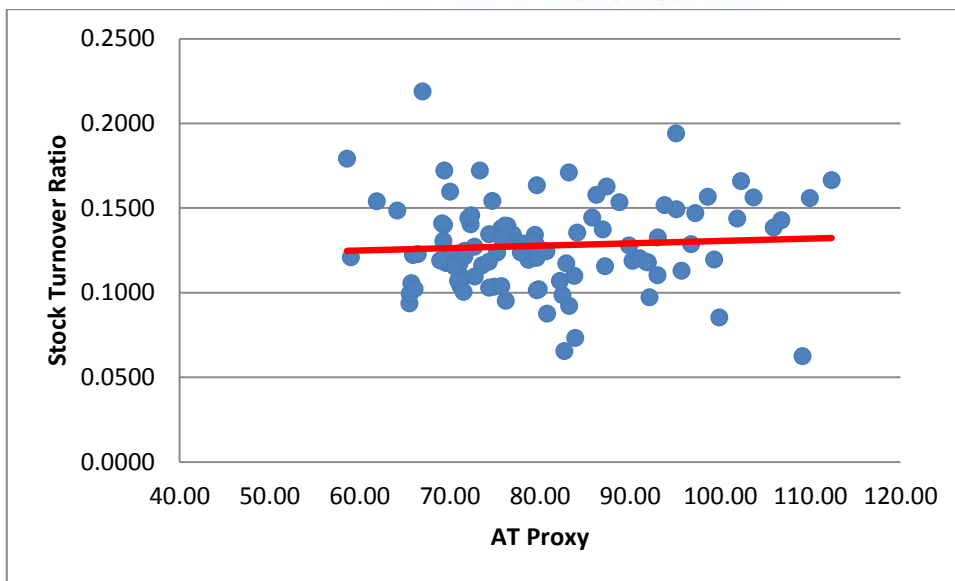
Figure 9: Scatter plot- Stock Turnover Ratio vs. AT Proxy

Figure 9 illustrates that there is a weak positive linear relationship between the stock turnover ratio and the AT Proxy. The relationship is weak due the slope of the trend line being only slightly upward tilted. Although the data points are concentrated around the trend line, there are a few data points on the extremities of the scatter-plot.

Table 4: Summarised Results for Hypothesis 3

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	0.000293051	0.000293051	0.425	0.516
Residual	98	0.06748768	0.00068865		
Total	99	0.067780731			
R squared	0.004323515				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	0.0001408	0.1165563
Standard Error	0.0002158	0.0176343
t-Value	0.6523376	6.6096368
p-Value	0.5157106	< 0.0001

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Correlation Matrix

	Stock Turnover Ratio	AT Proxy
Stock Turnover Ratio	1.00	0.066
AT Proxy	0.066	1.00

Table 5 is a summary of the results in Appendix E. The stock turnover ratio and the AT proxy are positively correlated. However, the strength of this relationship is weak at 0.066.

The R squared of the model is exceptionally low at 0.4%. Therefore, the model is only able to explain 0.4% of the variability of the dependent variable (proportional bid-ask spread).

The p-value of 0.51 is greater than the critical value of 0.10. With a 90% level of significance, we do not reject the null hypothesis. Therefore, no relationship exists between the stock turnover ratio and the AT Proxy.

5.2.4 Price impact measure and AT
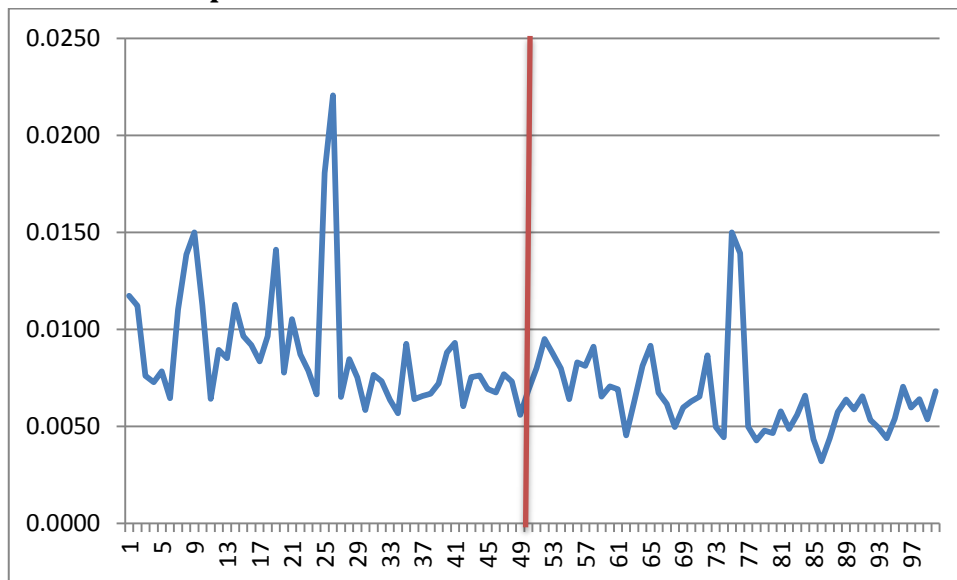
Figure 10: Price Impact Measure

Figure 10 is a graphical representation of the price impact measure for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There seem to be a

negative relationship between the time period prior to; and in the time period after the implementation of the new trading system. There also seems to be no change in the price impact measure slope after the implementation. Therefore, there seems to be a positive externality resulting from the new trading system.

Prior to the implementation of the new trading system, the standard deviation was 0.0032. During this period the price impact measure was in a slow declining phase. The price impact measure declined -41.56%, which is -0.85% per week. In comparison, the period following the implementation of the new system, the standard deviation was 0.0022. In this period the price impact measure continued to decline by -14.74%, which is -.030% per week.
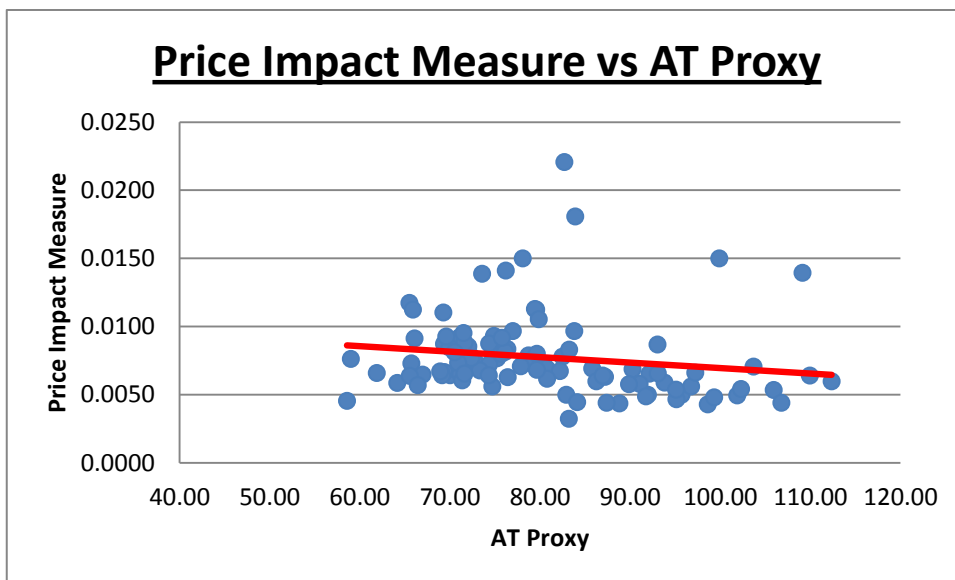
Figure 11: Scatter plot- Price Impact Measure vs. AT Proxy

Figure 11 illustrates that there is a weak negative linear relationship between price impact measure and the AT Proxy. The relationship is weak due to the slope of the trend line being only slightly downward tilted. The data points are concentrated around the trend line. However, there are a few outliers in the top right hand side of the scatter-plot.

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Table 5: Summarised Results for Hypothesis 4

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	2.37955E-05	2.37955E-05	2.759111	0.099898
Residual	98	0.000845186	8.62435E-06		
Total	99	0.000868982			
R squared	0.027383245				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	-4.0123E-05	0.01095462
Standard Error	2.41551E-05	0.001973432
t-Value	-1.661057317	5.551049179
p-Value	0.099898055	< 0.0001

Correlation Matrix

	Price impact ratio	*AT Proxy*
Price impact ratio	1.000	-0.165
AT Proxy	-0.165	1.000

Table 6 is a summary of the results in Appendix F. The price impact ratio and the AT proxy are negatively correlated, although the strength of this relationship is weak at -0.165.

The R squared of the model is low at 2.7%. Therefore, the model is able to explain 2.7% of the variability of the dependent variable (price impact ratio).

With a p-value of 0.0998, which is less than the critical value of 0.1, we can reject the null hypothesis and accept the alternative hypothesis. Therefore, a relationship exists between the price impact ratio and the AT Proxy.

5.2.5 Zero return measure and AT
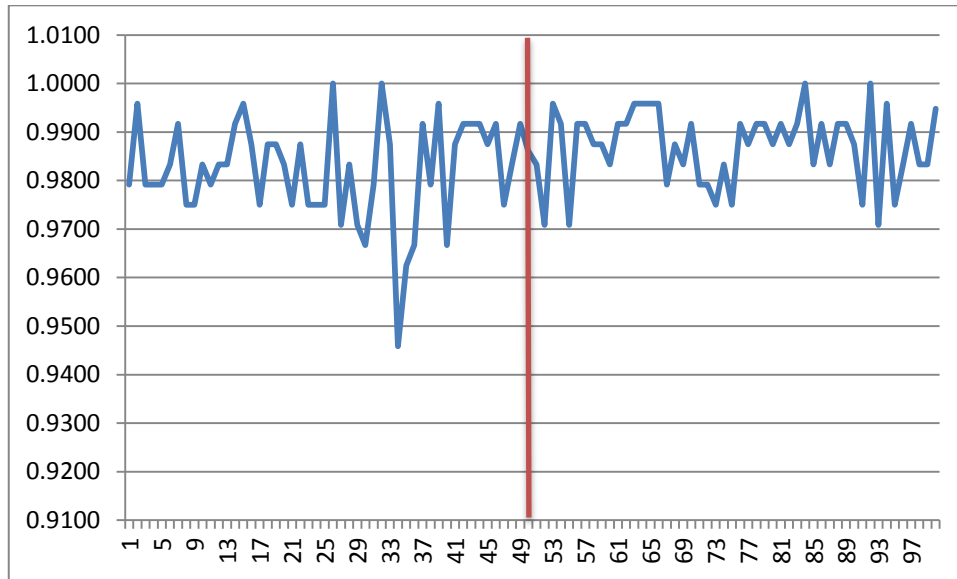
Figure 12: Zero Return Measure

Figure 12 is a graphical representation of the zero return measure values for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There seem to only be a slight positive relationship between the zero return measure and the implementation of the new trading system. There also seem to be a very slight increase in the zero return measure slope following the implementation. This increase in the slope could represent a positive externality of the new trading system on the zero return measure.

The standard deviation was 0.0104 prior to the implementation of the new trading system. During this period the zero return measure was relatively constant. The stock turnover ratio increased 0.71% for the period, and 0.01% per week. After the implementation of the new trading system the standard deviation was 0.0076. The stock turnover ratio exhibits a constant sideways trend, with a 1.17% increase during this period, which is a mere 0.02% increase per week.
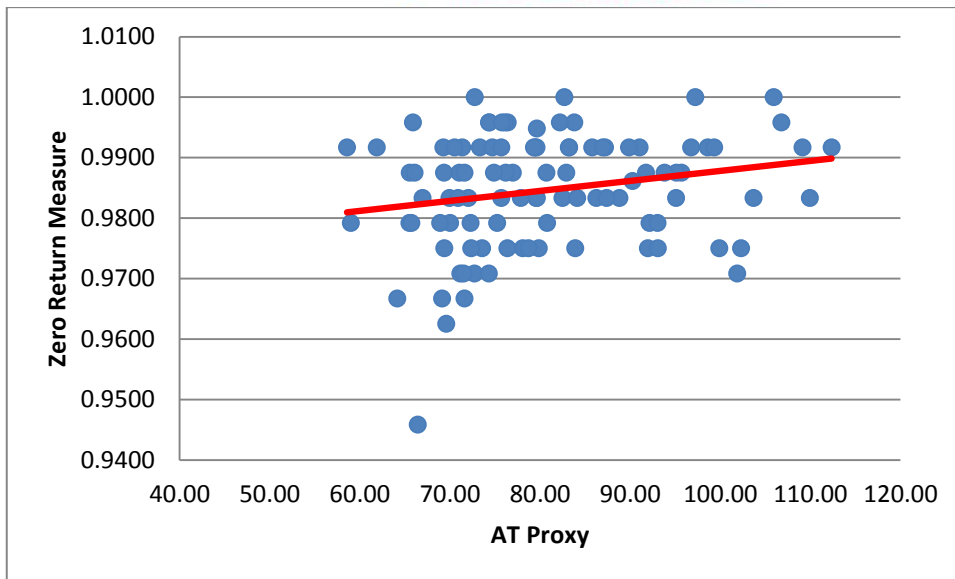
Figure 13: Scatter plot- Zero Return Measure vs. AT Proxy

From figure 13 it can be inferred that there is a positive linear relationship. The upward sloping trend line signifies that there is a weak negative relationship. A few outliers exist but the majority of the data points exist in a tight band surrounding the upward sloping trend line.

Table 6: Summarised Results for Hypothesis 5

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	0.00040543	0.00040543	4.74	0.031
Residual	98	0.00838166	8.55272E-05		
Total	99	0.00878709			
R squared	0.0461				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	0.000165618	0.971262304
Standard Error	7.60672E-05	0.00621457
t-Value	2.1773	156.2879
p-Value	0.0319	< 0.0001

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Correlation Matrix

	Zero return measure	AT Proxy
Zero return measure	1.000	0.215
AT Proxy	0.215	1.000

Table 7 is a summary of the results in Appendix G. The zero return measure and the AT proxy are positively correlated. However, the strength of this relationship is moderate at 0.215.

The R squared of the model is low at 4.6%. Therefore the model is able to explain 4.6% of the variability of the dependent variable (zero return measure).

The p-value is 0.0319, which is less than the critical value of 0.10. Therefore, with a 95% level of significance, we can reject the null hypothesis and accept the alternative hypothesis. Therefore, we can conclude that a relationship exists between the zero return measure and the AT Proxy.

5.4 Average trade size, volatility and AT

5.3.1 Volatility and AT Proxy
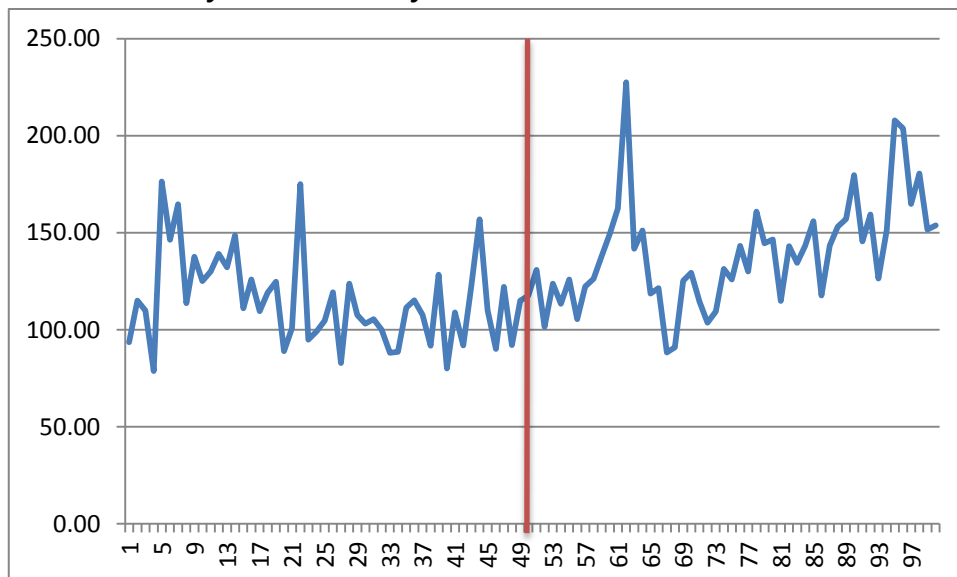
Figure 14: Share Price Volatility

Figure 14 is a graphical representation of the share price volatility for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform. There appears to be a positive relationship between share price volatility and the implementation of the new trading system. There also seems to be a change in the share price volatility slope following the implementation. This increase in the slope could represent a negative externality of the new trading system on the share price volatility.

Prior to the implementation of the new trading system, the standard deviation was 23.05. During this period, the share price volatility appears to follow a sideways trend. When comparing the first 5 week average to the last 5 week average for the period, there was a decrease of 8.35% in the share price volatility. After the implementation of the new trading system, the standard deviation was 27.95. When comparing the first 5 week average to the last 5 week average for the period, there was a significant increase of 51.76% in the share price volatility.
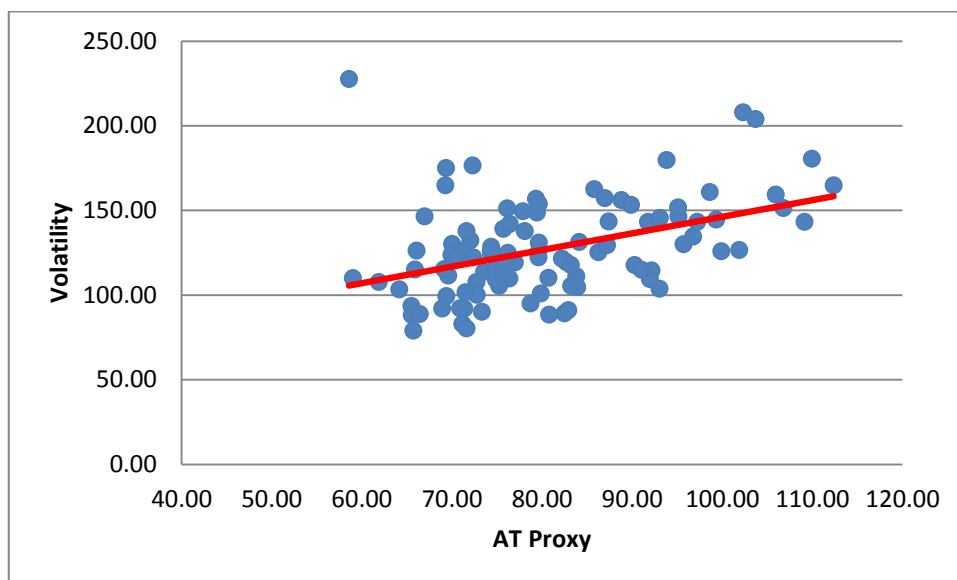
Figure 15: Scatter plot- Share Price Volatility vs. AT Proxy

Figure 15 illustrates that there is a weak positive linear relationship between the share price volatility and the AT Proxy. There is a moderate relationship between the variables due to the upward sloping trend line. The data points are concentrated

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around the trend line but there are a few outliers and the data points seems to disperse as the AT proxy increases.

Table 7: Summarised Results for Share Price Volatility and the AT Proxy.

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	14207.9482	14207.9482	21.227 0	< 0.0001
Residual	98	65594.7771	669.3345		
Total	99	79802.7252			
R squared	0.1780				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	0.9804	48.1532
Standard Error	0.2128	17.3852
t-Value	4.6073	2.7698
p-Value	< 0.0001	0.0067

Correlation Matrix

	Volatility	*AT Proxy*
Volatility	1.000	0.422
AT Proxy	0.422	1.000

Table 8 is a summary of the results in Appendix H. The volatility and the AT proxy are positively correlated, however the strength of this relationship is moderate at 0.422.

The R squared of the model is marginally low at 17.8%. Therefore the model is able to explain 17.8% of the variability of the dependent variable (volatility).

The p-value of <0.0001 is less than critical value of 0.10. With a 90% level of significance, we can reject the null hypothesis and accept the alternative hypothesis. Therefore a relationship exists between the share price volatility and the AT Proxy.

5.3.2 Average Trade size and AT Proxy
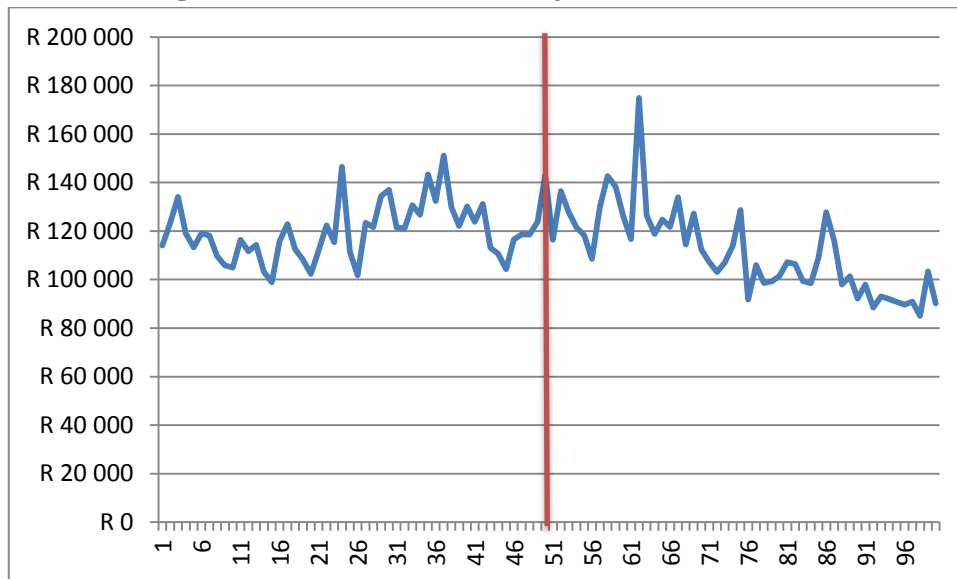
Figure 16: Average Trade Size

Figure 16 is a graphical representation of the average trade size value for the time period under investigation (2011/07/01 to 2013/06/28). The vertical line represents the implementation of the Millennium Exchange trading platform.

There appears to be a negative relationship between average trade size and the implementation of the new trading system. There also seems to be a change in the average trade size slope after the implementation. This decrease in the slope could represent a negative externality of the new trading system on the average trade size.

Prior to the implementation of the new trading system, the standard deviation was R11 973.18. During this period, the average trade size value was relatively flat, at around R120 000. After the implementation of the new trading system, the standard deviation was R17 614.84. This period saw a change in direction of the overall trend, from a flat trend into a downward sloping trend. The average trade size value decreased by 22.48% during this period, which equates to a -0.46% change per week.

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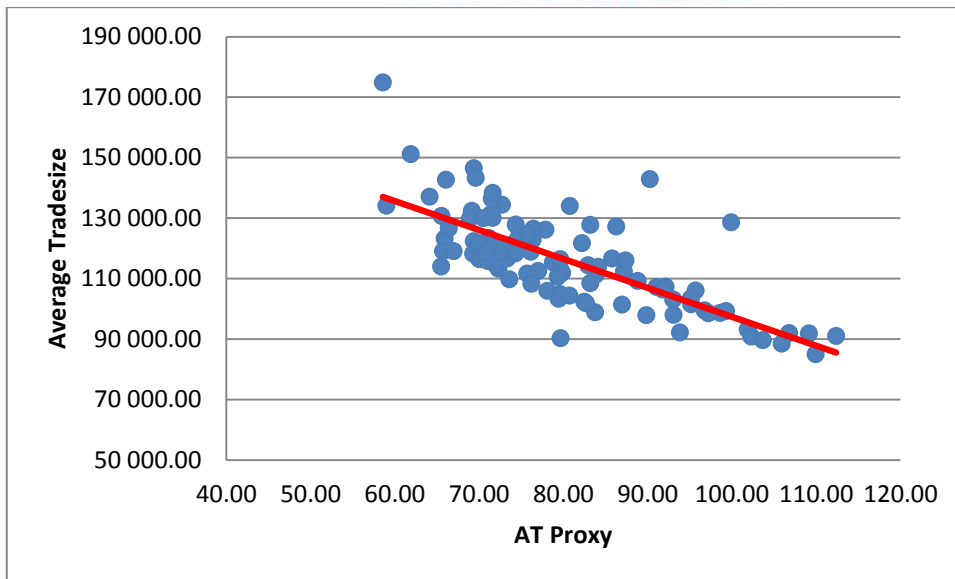
Figure 17: Scatter plot- Average Trade Size vs. AT Proxy

From figure 17 it can be inferred that there is a linear relationship which is negative in nature. The downward sloping trend line signifies that there is a strong negative relationship. A few outliers exist, but the majority of the data points exist in a tight band surrounding the downward sloping trend line.

Table 8: Summarised Results for the Average Trade Size and the AT Proxy.

Overall significance of the model

	Degrees of freedom	Sum of squares	Means squares	F ratio	p-Value
Regression	1	13518256954	13518256954	125.012	< 0.0001
Residual	98	10597300130	108135715.6		
Total	99	24115557084			
R squared	0.5606				

Significance of the model coefficients

	AT Proxy	Intercept
Coefficient	-956.3249	193026.6854
Standard Error	85.5322	6987.8506
t-Value	-11.1809	27.6232
p-Value	< 0.0001	< 0.0001

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Correlation Matrix

	Average trade size	AT Proxy
Average trade size	1.000	-0.749
AT Proxy	-0.749	1.000

Table 9 is a summary of the results in Appendix I. The average trade size and the AT proxy are negatively correlated. However, the strength of this relationship is strong at 0.749.

The R squared of the model is at a moderately high level of 56.1%. Therefore, the model is able to explain 56.1% of the variability of the dependent variable (average trade size).

The p-value is <0.0001 which is less than critical value of 0.10. With a 90% level of significance, we can reject the null hypothesis and accept the alternative hypothesis. Therefore, a relationship exists between the average trade size and the AT Proxy.

5.5 Summary and conclusion to results
Table 9: Summary of Results.

Hypothesis	R^2	Adjusted R^2	p-Value	Result
1) H_0: ATB > ATA H_1: ATB ≤ ATA	37.9%	37.3%	< 0.0001***	Reject H_o and accept H_1
2) H_0: PSpread ≥ 0 H_2: PSpread < 0	0.6%	-0.4%	0.439	Fail to reject H_o
3) H_0: STR ≤ 0 H_3: STR > 0	0.4%	-0.6%	0.516	Fail to reject H_o
4) H_0: PIR ≥ 0 H_4: PIR < 0	2.7%	1.7%	0.099898*	Reject H_o and accept H_4
5) H_0: Zero ≤ 0 H_5: Zero > 0	4.6%	3.6%	0.032**	Reject H_o and accept H_5
* statistically significant at 10% level ***statistically significant at 1% level				
**statistically significant at 5% level				

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The objective of the study required testing to ascertain whether or not AT activity was influenced by the implementation of the Millennium Exchange trading platform. Additionally, the study needed to test AT in relation to the liquidity of the JSE. The study used four measures of liquidity in order to capture and analyse this relationship.

The findings confirm that AT activity - measured through an AT proxy - was significantly affected by the implementation of the Millennium Exchange trading platform. The results varied significantly when investigating the relationship between AT and the liquidity of the JSE. AT seems to have a relationship with price impact ratio and the zero return measure.

Share price volatility and the average trade size seem to be adversely affected by AT.

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6. Discussion of Results

This chapter interprets the results obtained in chapter 5 and attempts to answer the research question objectives. The chapter is divided into the relevant sections as per the hypotheses set out in chapter 3. Each section will discuss the results from each test undertaken, compare it with literature and finally, will provide insight from the findings.

6.1 General comment

In general, results obtained indicate that the relationship between the AT proxy and the change in the market microstructure is statistically significant. This is in line with academic theory, in which AT becomes more prevalent due to improvements in market microstructure (Riordan & Storkenmaier, 2012).

The results in chapter 5 indicate that the relationship between the AT proxy and liquidity is mixed, as only two of the four liquidity measures returned a statistically significant relationship. The price impact measure and zero return measure returned a statistically significant relationship. Results obtained for the relationship between the AT proxy and the proportional bid-ask spread (Hendershott et al., 2011; Boehmer et al., 2012) as well as the stock turnover ratio (Hendershott et al., 2011) are statistically insignificant when compared to existing academic studies. However, the scatterplots confirm that the direction of their relationships is in line with existing literature.

Various reasons exist for this deviation from the literature. Firstly, this study was based on weekly measures, as opposed to monthly measures. Weekly measures are inherently statistically noisier than monthly measures, which could have affected the analysis. Secondly, the timeline under review in this study is focused on the two year period 2012-2013. Other studies' event windows have had much longer horizons - six to eight years as opposed to two years. Thirdly, the AT proxy only accounts for actual trades and not messages. Therefore there is no measurement of the price discovery process undertaken by AT. Finally, the JSE is an emerging market and its market structure is different in comparison to developed markets.

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The result of the liquidity measures correlation matrix confirms the choice of the liquidity measures employed in the study. Although the stock turnover ratio and the price impact measure are statistically correlated, none of the liquidity measures are highly correlated with each other. Therefore, it can be said that all four of the liquidity measures are measuring a portion of the total liquidity that are not measured by other liquidity measures.

In comparing the correlation results with those of Lesmond (2005), it can be confirmed that the relationship (positively-correlated) between the price impact measure and the proportional bid-ask spread are the same as the results achieved by Lesmond (2005).

Boehmer et al. (2012) indicated that a few firms are responsible for an unequal portion of the message traffic and trades. If the mean of the variable (number of trades) exceeds the median of the variable (number of trades) it indicates that a few firms are responsible for the number of trades. In this study, the number of trades exceeds its median by 5.5%. This indicates that only a few firms are responsible for a large portion of the trades. This is a trend seen in other emerging market, such as Shanghai (Boehmer et al., 2012). This high market concentration adversely affects liquidity. If only a few firms are responsible for most of the trades on the JSE, it means that they will have an information advantage over other traders. This information advantage can occur through their own AT price discovery process. They will also have an enhanced view of the order book and will then be able to reduce the effect of anonymity in the market, due to the size of their own trading book.

A concern looked at in this research project was the lack of immediate reaction to the change of the market microstructure due to implementation of the Millennium Exchange trading platform. Literature presented in chapter 2, particularly that of Hendershott et al. (2011) and Boehmer et al. (2012), indicated in their data a clear immediate reaction to a change in market microstructure. A possible reason for this lack of immediate reaction could be due to a conservative stance taken by financial institutions and traders when trading on the new system. Although the lack of reaction was a concern, there was a statistical relationship between the event and AT.
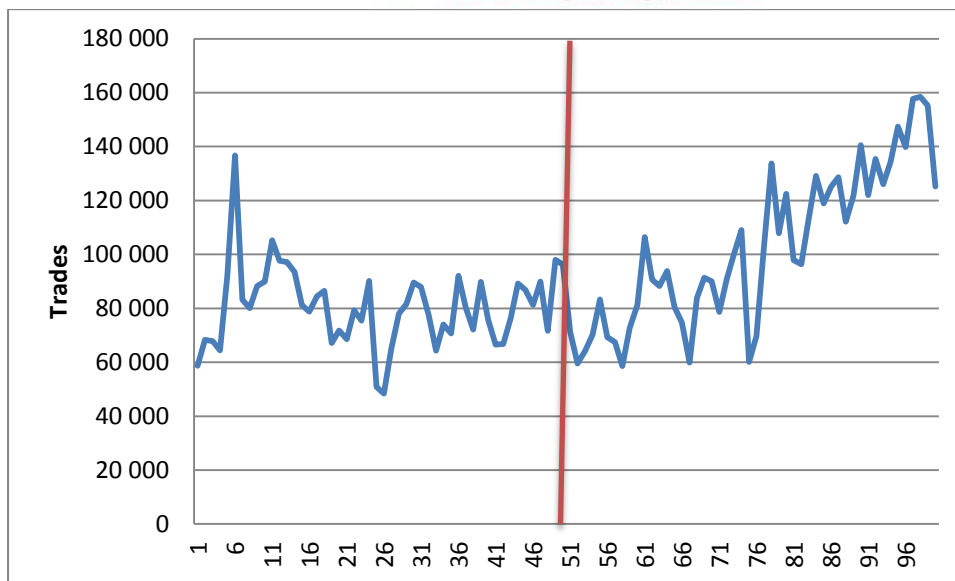
Figure 18: Number of Trades

An alternative reason could be that a number of financial institution experienced technical difficulties in the first weeks on the Millennium Exchange trading platform. This led to a lower level of trading activity. Figure 18 provides evidence in confirming the probability of lower trade numbers due to technical difficulties or the conservative stance taken by traders and financial institutions. It can be seen how the number of trades initially fell in week 51 and remained low until week 60. It was expected from week 51 that the amount of recorded trades were to exceed the previous week's total number.

From an analysis of the descriptive statistics, it can be noted that a majority of the liquidity measures exhibit a level of skewness. The proportional bid-ask spread; stock turnover ratio; and the price impact measure; display positive skewness while the zero return measure indicates negative skewness. The AT proxy exhibits no skewness and is normally distributed. The data employed exhibits autocorrelation tendencies as per the Durbin-Watson scores being closer to 1 than the required 2.

6.2 Hypothesis 1: AT Proxy and the Implementation of the Millennium Exchange Trading System

From the literature presented in chapter two it was expected that there would be a statistically positive relationship between AT Proxy and the implementation of the

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Millennium exchange trading system. From figure 5 it can be seen that the AT Proxy nearly doubled for the two year period. The growth in AT proxy accelerated after the change to the new trading system.

From results of the regression analysis in table 2, it can be observed that there is a statistically significant positive relationship between AT and the change in the trading system. This relationship is statistically significant as the p-value is < 0.0001, which is less than the critical value of 0.1. Therefore we reject the null hypothesis and accept the alternative hypothesis.

The results of Hendershott et al. (2011) confirm the results achieved in this study. Hendershott et al. (2011) also proved that there was a positive relationship between the AT proxy and the dummy variable, which represents the change in trading system.

Boehmer et al. (2012) results confirm the results of this study. Boehmer et al. (2012) reported that the number of quote and trade messages annually per stock increased for the JSE by 1025% for the 2001-2009 period. The results of this study showed that the AT proxy grew 100% for the 2011-2013 period. The number of trades grew by 63.9% prior to the implementation of the new system, while the number grew by 75.5% after the implementation of the new trading system. Over the two year period, the amount of trades grew by 109%. Boehmer et al. (2012) also reported that the AT proxy had a positive relationship with the implementation of co-location facilities (change in the market structure).

The growth in AT from the change in trading environment found in this study coincides with results of Riordan and Storkenmaier (2012). Riordan and Storkenmaier (2012) investigate how latency upgrades on the DAX affect its market quality and liquidity. They looked at the QV Ratio, which is the number of quotes standardized by trading volume in 10,000 euros. This ratio almost doubled (91%) after the upgrade, which lowered the latency speeds on the DAX. The QV Ratio is seen to have had a statistically significant positive relationship with the new upgraded system. The QV ratio is also seen to have improved for the top quintile of shares with the highest market capitalisation from a pre 0.79 level to a post 1.70 level, therefore having increased by

115%. The results are similar to this study, in that there is a statistically positive significant relationship between the AT proxy and the Millennium Exchange trading platform. Drawing from the results obtained in chapter 5 in comparison to academic literature shows that a relationship exists between AT and the implementation of the new trading system. Market microstructure improvements (in terms of latency improvements) appear to increase the activity levels of AT.

6.3 Hypothesis 2: Proportional Bid-Ask Spread and AT

From the literature presented in chapter two it was expected that there would be a statistically negative relationship between the AT Proxy and the proportional bid-ask spread. From figure 6 it can be seen that the proportional bid-ask spread continually narrowed up until the implementation of the new trading system. After the implementation, the proportional bid-ask spread remained constant at 0.10. There is a large uptick in the last week of the study, which is due to the last week being a 4 day week. This would cause the results of that week to weigh heavily on the proportional bid-ask spread calculation. The scatterplot and correlation matrix confirms this negative relationship.

From results of the regression analysis in table 4, it can be stated that the proportional bid-ask spread is negatively related to AT. However, this negative relationship is statistically insignificant because the p-value is 0.439, which is greater than critical value of 0.1. Therefore we accept the null hypothesis.

The results obtained from this study suggest that the relationship is negative in nature, which is confirmed by the scatterplot. This negative relationship between the AT Proxy and the proportional bid-ask spread, with a coefficient of -0.000172108, is similar when compared to academic literature. However, the relationship is statistically insignificant.

The possible reason for the insignificant result could be due to the AT proxy. The AT proxy measures only trades and not message orders. Therefore the AT proxy is unable to account for incomplete bids and offers which would affect this measure. Since the

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AT proxy cannot account for these orders, it stands to follow that this result is not as expected.

Another possible reason for this insignificant result could be due to the JSE market structure being different to developed markets. From previously stated literature (JSE Limited, 2013c) the JSE will only be comparable to developed markets when co-location facilities are implemented in the first quarter of 2014. Being classified as an emerging market, the JSE faces different challenges when compared to developed markets in terms of illiquidity and high market concentration issues (Gobodo, 2007). These factors differentiate the JSE from developed markets and could attribute to the insignificant result.

Below is supporting literature pertaining to hypothesis 2 as well as comparisons of the results gathered by this study and other international studies.

Hasbrouck and Saar (2013) results show that an increase in low latency activity (AT) resulted in the narrowing of quoted spreads. The study focused mainly on the effects of low-latency activity on various spread measures on the NASDAQ for the period 2007-2008. Their results indicate that the proportional bid-ask spread reduced from 0.35 in 2007 to 0.3 in 2008 (Hasbrouck & Saar, 2013). The effective bid-ask spread also narrowed from 0.45 in 2007 to 0.39 in 2008 (Hasbrouck & Saar, 2013).

Boehmer et al. (2012) investigated the relationship between AT and the bid-ask spread component of liquidity via the "quoted spread" and "relative effective spread," as opposed to the proportional bid-ask spread. In principle these liquidity measures measure the same component of liquidity and are therefore comparable. Boehmer et al. (2012) results indicate that there is a statistically negative relationship between the AT proxy and the relative spread measures. The relative effective spread and quoted spread improved (bid-ask spread narrowed) on an annual basis from 2002 until 2007. In 2008 both measures worsened (the bid-ask spread grew wider). This increase was mainly due to the effects of the financial crisis of 2007-2008. In the results of Boehmer et al. (2012) both bid-ask spread measures improved across 92% of the markets

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investigated (in both developed and emerging markets). In terms of the spread, improvement in liquidity is largely located in the highly and medium liquid equities.

Hendershott et al. (2011) results indicate that the bid-ask component of the liquidity had improved throughout the 2001-2006 period. There is a statistically negative relationship between the AT proxy as well as in quoted and effective bid-ask spread.

With an increase in AT activity, it can be expected that the increased competition in the market to execute orders at better levels will result in the narrowing of spreads (Foucault & Menkveld, 2008). Increase in AT activity leads to a lowering of trading costs through improvement in adverse selection, whereby the bid-ask spreads narrows (Hendershott et al., 2011). The uptake of AT in the market has increased levels of efficiency (Boehmer et al., 2012). This reduces the effect of adverse selection.

6.4 Hypothesis 3: Stock turnover ratio and AT

From the literature presented in chapter two it was expected that there would be a statistically positive relationship between AT Proxy and the stock turnover ratio. From figure 8 it can be seen that the stock turnover ratio was constant before the implementation of the new trading system, and increased after the implementation of the new trading system. The scatterplot and correlation matrix confirm this positive relationship. From results of the regression analysis in table 5, it can be noted that there is a positive relationship between the AT proxy and the stock turn ratio. The relationship is, however, statistically insignificant.

From results of the regression analysis in table 5, it can be stated that the stock turnover ratio spread is positively correlated with AT. However, this positive relationship is statistically insignificant because the p-value is 0.515711 which is greater than the critical value of 0.1. Therefore we accept the null hypothesis.

The results obtained from this study suggest that the relationship is positive in nature as confirmed by the scatterplot. This positive relationship between the AT Proxy and the stock turnover ratio, with a coefficient of 0.0001408, is similar when compared to academic literature. However, the relationship is statistically insignificant.

The possible explanation for the statistically insignificant result could lie with the general illiquidity of the JSE. As stated in chapter 1, figure 1 (World Federation of Exchanges, 2013) emerging markets are generally illiquid when compared to developed markets. This could be the reason for the insignificant result. Gobodo (2007) cites a possible reason for the illiquidity: the departure of our largest companies to seek primary listings offshore. 6 of the 10 top listed companies on the JSE have dual or primary listings outside of South Africa. Because this allows foreign investors to transact on their home exchanges there has been a detrimental effect on the volume traded in these shares on the JSE. Below is supporting literature pertaining to hypothesis 3, as well as comparisons of the results gathered by this study and other international studies:

Foucault et al. (2013) developed a model designed to explore the maker/taker pricing model (make and take fees) and to illustrate how this pricing model interacts with AT. The results produced by the model in Foucault, et al. (2013) indicate that there is a strong relationship between AT and the trading rate, which ultimately increases the volume traded. With monitoring costs reduced, market makers trade at more efficient levels, therefore enabling market takers to trade more often. The result of this reduction in monitoring costs; afforded by technology innovations (AT); as well as a balanced trading cost schedule, is encouraged liquidity through higher levels of trading. This should positively affect the stock turnover ratio.

Hendershott et al. (2011) investigated the relationship between the AT proxy and non-spread variables, of which one is a share turnover. The share turnover is an annual share turnover figure. This is not the same as the stock turnover ratio but is a generalised ratio depicting the turnover of the market, and is comparable to the stock turnover ratio. Hendershott et al. (2011) results indicate that there is a positive relationship between the share turnover coefficient and the AT Proxy for the most liquid quintile of shares. However, this positive result of Hendershott et al. (2011) is statistically insignificant the same as the result of this study.

Jain (2005) investigated the impact of automation of 120 exchanges. Jain (2005) findings indicated that there was reduction in equity premium, especially in emerging countries. In terms of liquidity, the lowering of the equity premium resulted in an increase in trading volume. Therefore, the share turnover ratio should display a positive relationship with AT. This is due to automation of the stock exchanges, allowing for greater uptake of AT (Aldridge, 2013) which coincided with an increase in volume traded.

Since the implementation of the new trading platform Millennium Exchange, the number of trades has increased by 57%; volumes by 4% and value of trades by 21% (JSE Limited, 2013b). These figures stated in the JSE press release should serve as further evidence that the stock turnover has increased.

6.5 Hypothesis 4: Price impact measure and AT

From the literature presented in chapter two it was expected that there would be a statistically negative relationship between AT Proxy and the price impact measure. From figure 10 it can be seen that the price impact measure had a downward trend before the implementation of the new trading system. After the implementation of the system, the ratio continued with the negative trend, but at a consistently lowering rate. The scatterplot and correlation matrix confirm this negative relationship.

From results of the regression analysis seen in table 6, it can be observed that there is a statistically significant negative relationship between the price impact measure and the AT proxy, as the p-value of 0.09989 is less than the critical value of 0.1. Therefore we reject the null hypothesis and accept the alternative hypothesis.

The results obtained from this study suggest that the relationship is negative in nature, as confirmed by the scatterplot. This negative relationship between the AT Proxy and the price impact measure, with a coefficient of -4.0123E-05, is similar but smaller when compared to academic literature.

The price impact measure is able to measure 2 out of the 4 components of liquidity: depth and resiliency. However, in this study we have not calculated the average and are this not able to comment on this aspect. From hypothesis one, and from regression

analysis of the relationship between AT the average trade size, it can be seen that the AT activity in trade has increased. It can be deduced that as AT levels increase, trades become smaller. With greater amounts of small trades it is expected that the price impact effect will reduce, resulting in an increase of the resiliency of the share.

The relationship between AT and volatility is significant and exacerbates the price impact effect. After the implementation of the new trading system, the standard deviation of the share price volatility increases by 21.3%. In terms of the order book, this illustrates that there are a significant amount of orders that lie near or around the spread. However, when a large market order is placed there is the possibility that it will break through the wall of orders surrounding the spread, and will therefore significantly increase or decrease the price. Although it appears that the market depth of the order book has been reduced, there is a greater number of orders lying near and around the spread. Thus it appears that large orders cannot be absorbed by the market without significantly altering the price. With the level of AT activity increasing, and the price impact effect improving intuitively, the size of the trades is decreasing while the number of trades is increasing.

Below is supporting literature pertaining to hypothesis 4, as well as comparisons of the results gathered by this study and other international studies:

Hendershott et al. (2011) measured the relationship between the AT proxy and the price impact measure via an adverse selection variable based on the 5-minute price impact of a trade calculation. Hendershott et al. (2011) regression results indicate that at a 95% level of significance there is a negative relationship between the AT proxy and the adverse selection variable (based on price impact calculation). This result held true for each quintile of shares from the most liquid to the least liquid of shares.

Boehmer et al. (2012) results confirm the results of this study. The results of Boehmer et al. (2012) indicate that there is a statistically negative relationship between the AT proxy and the price impact measure (labelled Amihud measure in Boehmer et al., 2012). This relationship is confirmed for the shares with the highest price and with the

highest market capitalisation. This relationship does not hold true for the lesser priced and low market capitalised shares.

Aldridge (2013) illustrated how successful the uptake of AT has been over the past decade. One of the major reasons stated for AT usage (refer to figure 3) was the reduction in the market impact effect. One of the most important tasks undertaken by AT is the breaking of large orders into smaller ones, which reduces the price impact effect.

Riordan and Storkenmaier (2012) results indicate that improvement in the market micro structure (i.e. improved latency speed) led to a reduction in the price impact measure. As stated in hypothesis (1), Riordan and Storkenmaier (2012) make use of QV Ratio as a measure of market activity and found that there is a statistically significant positive relationship between the new upgraded trading system and the price impact measure. The two cited findings confirm the results found in this study.

6.6 Hypothesis 5: Zero Return Measure and AT

From the literature presented in chapter two it was expected that there would be a statistically positive relationship between AT Proxy and the zero return measure. From figure 12 it can be seen that the zero return measure has a consistent sideways trend prior to the implementation of the new trading system. After the implementation it shoes that while the constant sideways trend remains, the range has narrowed to a tighter band of 0.97 and 1. The scatterplot depicts a positive relationship between AT and the zero return measure.

From results of the regression analysis in table 7, it can be noted that there is a statistically significant positive relationship between the zero return measure and the AT proxy, as the p-value of 0.031 is less than the critical value of 0.1. Therefore we reject the null hypothesis and accept alternative hypothesis.

The results obtained from this study suggest that the relationship is positive in nature, as confirmed by the scatterplot. This positive relationship between the AT Proxy and the zero return measure, with a coefficient of 0.000165618, is similar when compared to academic literature.

The usage of the zero return measure is based on the fact that informed investors would only trade if the profit was expected to exceed the transaction costs. Therefore, the trader would not trade if the value of the information did not compensate for the cost of trading. In times of low liquidity, traders seeking liquidity will avoid shares with high transaction costs.

From the results in the study it appears that the increase in AT activity has led to an increase in the amount of trades taking place in the market. The increase in AT activity has led to a more efficient way of trading. This has reduced the cost of trading i.e. by trading in smaller size orders (increase in the zero return measure). The author is unable to confirm the follow statement, but surmises that the increase in AT activity led its own price discovery allows for the value of information to compensate for the cost of trading. However, due to the AT Proxy being trade-based and not message-based, this hypothesis remains without proof.

Carrion (2013) concluded that AT has the ability to trade more profitable. This is due to the AT having the ability to incorporate price information from order flow and market wide information more efficiently when AT participation is high. Therefore, with higher levels of AT activity, it is expected that AT will trade more often and more effectively. Thus it is expected that AT and the zero return measure will exhibit a positive relationship. This is confirmed in this study as per table 5.

6.7 Extra context Average trade size and share price volatility.

6.7.1 Share price volatility and the AT proxy

From the literature presented in chapter two, there are contrasting findings and perceptions relating to the relationship between the AT proxy and share price volatility. From figure 14 it can be seen that share price volatility has a consistent sideways trend pre-implementation of the new trading system, ranging between 100c and 150c. After the implementation there was a change in the trend from the consist sideways trend to an upward trend. The scatterplot depicts a positive relationship between AT and share price volatility. The correlation matrix confirms this relationship.

From results of the regression analysis in table 8, it can be observed that there is a statistically significant positive relationship between the share price volatility and the AT proxy, as the p-value of < 0.0001 is less than the critical value of 0.1.

The results obtained from this study suggest that the relationship is positive in nature, as confirmed by the scatterplot. This positive relationship between the AT Proxy and the zero return measure, with a coefficient of 0.000165618, is similar when compared to academic literature.

Following the results in section 6.5 - hypothesis 4 - it can be seen that price impact has decreased as the AT levels have picked up. The order book has altered and has resulted in an increase of orders lying around the spread, but the order deep in the order book (market depth) has decreased. The increase in the average share price volatility has increased from an average of 114.86c before the event, to 139.81c after the event (21.72% increase). Therefore, it appears that once the wall of orders surrounding the spread is broken, there are very few orders in the background. It also seems to be that once the breakout has occurred, AT activity reduces and does not come back into the market to correct the break-out of the spread. This assertion is speculative as the AT proxy is based on trades (only measuring trades) and a conclusive statement could have been made if an AT proxy based on messages was employed in the study.

Below is supporting literature pertaining to AT and share price volatility, as well as comparisons of the results gathered by this study and other international studies:

Hendershott et al. (2011) results, in terms of the relationship between AT and volatility, indicates that there is a statistically positive relationship between the two variables at a 95% level of significance. The quoted market depth for the most liquid quintile of shares fell from $1 750 000 to $900 000: almost a 50% decrease. This reduction of the quoted market depth is a contributing factor to the increase in volatility, as large orders cannot be absorbed by the market without significantly altering the price; in line with the results of hypothesis 4 (AT and the price impact ratio.)

Boehmer et al. (2012) results indicate that volatility worsened across both developed and developing markets with the introduction of AT. Boehmer et al. (2012) investigated the relationship between AT and volatility in depth. Boehmer et al. (2012) regressed 5 different measures of volatility against the AT proxy. All 5 measures returned a statistically significant relationship with AT. Boehmer et al. (2012) attributes the increase in volatility to the reduction of the quoted depth of shares on the order book. When depth of the order book decreases, the likelihood of volatility increases, as large orders are unable to be absorbed by the order book and the price of the share will fluctuate greatly.

6.7.2 Average trade size and the AT proxy

From the literature presented in chapter two, it was expected that there would be a statistically significant negative relationship between AT Proxy and the average trade size. From figure 16 it can be seen that the average trade size has a consistent sideways trend prior to the implementation of the new trading system. Post-implementation it can be seen there is a drastic shift into a downward trend. The scatterplot depicts a negative relationship between AT and the average trade size, which is confirmed by the correlation matrix. From results of the regression analysis in table 9, it can be noted that there is a statistically significant negative relationship at a confidence level of 99%.

From results of the regression analysis in table 9, it can be observed that there is a statistically significant positive relationship between the share price volatility and the AT proxy, as the p-value of < 0.0001 is less than the critical value of 0.1.

The results obtained from this study suggest that the relationship is positive in nature, which is confirmed by the results shown in the scatter-plot. This positive relationship between the AT Proxy and the average trade size, with a coefficient of -956.3249, is similar when compared to academic literature.

One of the primary functions of AT is to break large orders into smaller ones. This is confirmed by the results in this study, as figure 16 illustrates how the average trade

size has decreased over the two year period by 22.48%. Figure 18 illustrates the amount of trades has increased over the period as has AT activity, figure 5.

Hendershott et al. (2011) results denote that there is a negative relationship between average trade size and the AT proxy. Hendershott et al. (2011) also confirms that the relationship is statistically significant at a 95% level for the most liquid quintile of shares. Interestingly the average trade size is adversely affected by AT for only the most liquid shares and not for the less liquid ones. Hendershott et al. (2011) is also able to confirm what many market commentators and academics suspect, that an increase in AT is highlighted as one of the causes of smaller average trade sizes over the last few years. With the level of AT activity increasing and the price impact effect improving intuitively, the size of the trades is decreasing and number of trades is increasing.

6.8 The impact of the findings on the JSE

AT activity has increased significantly since the implementation of the new trading system. This increase in activity appears to have decreased the average trade size but increased the volatility.

In terms of the liquidity of the order book the following effects were noticed:

- The "immediacy" measured by the stock turnover ratio improved, as confirmed by the scatter-plot, but is statistically insignificant.
- The" tightness and width" measured by the proportional bid offer spread improved in the right direction, as confirmed by the scatter-plot, but was statistically insignificant.
- In terms of "depth" and "resiliency" the price impact measure moved in the right direction, as confirmed by the scatter-plot, and was statistically significant. It seems to be that the resiliency improved but it is suspected that the depth has decreased.

It seems that the increase in AT activity has decreased the cost of trading, which is achieved by trading in smaller sized orders. This has led to an increase in the zero return measure.

6.9 Summary

In this chapter, we have explored the results of the study as obtained through the regression analysis. These findings were then discussed based on the research objectives. The results of the study indicate that there is a significant relationship between AT and the change in the market microstructure. However, in terms of the relationship between AT and liquidity the result is mixed, with only the price impact measure and the zero return measure significantly related to AT. Increase in AT activity appears to have increased the share price volatility, but has reduced the average trade size.

7. Conclusions

The concluding chapter provides a summary of the findings presented and discussed in chapter five and six of this study. Recommendations are provided for relevant stakeholders and future research. Research limitations encountered by the author are discussed in this chapter.

7.1 Summary and Conclusions

This study investigated the level of AT on the JSE and what effect the implementation of the Millennium Exchange trading platform had on AT activity.

The same type of AT proxy as used in other research dealing with the same topic (Hendershott et al., 2011; Boehmer et al., 2012) was employed. The AT proxy was employed in the study to measure the level of AT activity in the JSE .The study then investigated the relationship between AT and the liquidity of the JSE. The liquidity was measured via four low-frequency liquidity measures: the stock turnover ratio, the proportional bid-ask spread, the price impact ratio, and the zero return measure.

There was a strong positive statistical relationship between AT and the implementation of the Millennium Exchange trading platform. AT activity grew by 24.05% after the implementation of the new trading system, as compared to only 9.62% prior to the implementation. This increase in AT activity, owing to a change in the market microstructure, is in line with international theory as proposed by Hendershott et al. (2011); Boehmer et al. (2012); and lastly, Riordan and Storkenmaier (2012).

In terms of the relationship between AT and liquidity, the result is mixed. Only two of the four liquidity measures returned statistically significant relationships, namely the price impact ratio and the zero return measure. The stock turnover ratio and the proportional bid--ask spread returned statistically insignificant results. However, their scatter-plots reveal that their relationship with AT was in the correct direction.

The extra content included in the study proved useful in the analysis of the research questions. The results of this extra content allowed the author to make inferences regarding the interaction of the AT proxy, volatility, average trade size, and the liquidity measures.

The increase in AT activity has led to an increase in the share price volatility, and a decrease in the average trade size.

In terms of the different dimensions of liquidity, the "immediacy" measured by the stock turnover ratio improved, but it produced a statistically insignificant result in terms of its relationship with AT. Therefore, this improvement in the "immediacy" could be the result of another unknown factor.

The "tightness and width" component of liquidity, as measured by the proportional bid-offer spread, improved. However, it produced a statistically insignificant result in terms of its relationship with AT. Therefore, the improvement in the "tightness and width" of liquidity could be the result of another unknown factor.

This unknown factor could be attributed to the fact that the JSE is classified as an emerging market. The market structure of the JSE still requires one more evolution (co-location) in order for it to match the market structures of developed markets. The current market structure of the JSE could be adversely affecting AT and liquidity. The JSE regulations cannot be cited as a reason for this difference, as the regulations are superior to developed markets (JSE Limited, 2011b).

The "depth" and "resiliency" component of liquidity, as measured by the price impact measure, improved and produced a statistically significant relationship with AT. The key insight provided by this particular result is invaluable. The increase in AT activity has resulted in an increase in trade, but the average size of these trades has considerably reduced. The reduction in the price impact effect (measured via the price-impact measure) signifies that there is an increase in the resiliency of the order book. However, the increase in the share price volatility suggests that once the initial group of orders surrounding the bid-ask spread is exhausted, there are not enough orders lying deep in the order book to prevent wild fluctuation in the price.

In conclusion, the study found that the level of AT was positively affected by the implementation of the Millennium Exchange trading platform. The increase in AT seems to have had a mixed effect on the liquidity of the JSE. AT seems to have increased the volatility of the market and decreased the average trade size.

7.2 Recommendations to Relevant Stakeholders

Due to the increased volatility associated with the increase in AT activity, the author would recommend altering the rules pertaining to AT in the JSE. Specifically, he would recommend that once AT places an order in the market, that order should then rest there for a minimum period of time. This would force AT to change its trading strategy and to be more selective in choosing trades and lower volatility. This would stop AT from flashing orders in and out of the market, preventing flash crashes.

Secondly, the author would recommend that the JSE increase the trading cost when ATs place a market order (demanding liquidity), and provide a rebate to ATs who place limit orders in the market (provide liquidity). This adjustment in the pricing structure would promote liquidity in times of illiquidity, as well as increase the depth of the order book.

7.3 Recommendations for Further Research

Areas of consideration for future research may include:

- A future study is suggested whereby high frequency data (Goyenko et al., 2009) is employed to construct the relevant high frequency liquidity measures and AT proxy. The timeline for the study should be extended to cover the implementation of the co-location facilities, therefore allowing the new research to confirm and build onto the results of this study.

- From the first quarter of 2014, the JSE will be offering co-location services to financial institutions (change in market microstructure). The timeline for a future study should be extended to cover the implementation of these co-location facilities, therefore allowing the new research to confirm and build onto the results of this study.

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- The inability to acquire specific AT messages and trade data requires the use of an AT Proxy. Future research should investigate which of the generally accepted AT proxies, the QV ratio (Riordan & Storkenmaier, 2012) and AT proxy (Hendershott et al., 2011) provides the truest measure of AT activity.

- OLS regression has been criticised in the past as being too simplistic. Therefore, a more sophisticated modelling technique may be used in future research. An event study model may be employed in future research in order to confirm and build onto the results obtained in this study.

- With the relationship between AT and liquidity being established in this study, it is recommended that future research should focus on the relationship between AT and price discovery. Future research will hopefully provide insight and a better understanding on whether AT changes the nature of price discovery.

- According to descriptive statistics utilised, the liquidity measures exhibited skewness (positive and negative). Therefore the analysis should be extended to include transformed versions of the liquidity measures as well as new liquidity proxies.

7.4 Research Limitations

Limitations the author encountered while completing the study included:

- The small sample size was a large limiting factor of the research. Previous studies have based their analysis of the AT proxy or QV ratio on at least 6 to 8 years' worth of monthly data. By employing a smaller data set, any deviations in the data caused by external events can skew the data and make it exceedingly difficult to draw valuable conclusions from the study.

- The series of liquidity measures employed is in no way complete. The most effective measures were discovered by consulting academic literature together with the availability of financial data, which were then included in the analysis.

- A new, adapted AT proxy based on number of trades per 1000 shares of volume traded was employed, instead of number of electronic message per $100 of trading volume, as cited in academic literature. The need to develop an

adapted AT proxy stems from the fact that the author was unable to secure a complete data set of the daily message flow from the JSE. The new AT proxy was able unable to account for AT price discovery process, which is measured via messages instead of trades.

- The lag time in the reaction to the change in market microstructure is uncharacteristic in comparison to international evidence. It is unknown how this lagged reaction affected the analysis of the data.

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Appendix A - Summary of Descriptive Statistics

	Stock Turnover Ratio	Proportional Bid Ask Spread	Price Impact Ratio	Zero Return Measure	AT Proxy	Volatility	Average Tradesize	Trades
Mean	0.13	0.12	0.01	0.98	80.79	127.36	115 766.36	91 451.06
Variance	0.00	0.00	0.00	0.00	149.31	806.09	243 591 485.70	638 475 107.43
Std. Dev.	0.03	0.03	0.00	0.01	12.22	28.39	15 607.42	25 268.06
Skewness	0.36	1.49	2.08	-0.94	0.65	0.84	0.53	0.86
Kurtosis	4.00	5.64	9.22	4.74	2.77	4.13	4.06	3.11
Median	0.12	0.11	0.01	0.99	78.10	123.79	115 800.84	86 872.40
Mean Abs. Dev.	0.02	0.02	0.00	0.01	9.93	22.02	12 163.61	19 730.59
Mode	0.12	0.10	0.01	0.99	79.64	122.26	121 446.19	90 056.73
Minimum	0.06	0.09	0.00	0.95	58.57	78.78	85 000.73	48 337.20
Maximum	0.22	0.22	0.02	1.00	112.36	227.52	174 833.39	158 471.60
Range	0.16	0.14	0.02	0.05	53.79	148.74	89 832.66	110 134.40
Count	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sum	12.79	12.12	0.77	98.46	8 078.88	12 735.99	11 576 635.88	9 145 105.60
1st Quartile	0.11	0.10	0.01	0.98	71.50	107.57	104 291.95	71 718.60
3rd Quartile	0.14	0.13	0.01	0.99	88.82	144.46	124 686.37	102 268.40
Interquartile Range	0.03	0.03	0.00	0.01	17.31	36.89	20 394.42	30 549.80

Appendix B - Statistical Output. Hypothesis 1: Implementation of the Millennium Exchange trading platform and AT

Descriptive Statistics

	Mean	Std. Deviation	N
AT Proxy	80.788782	12.2190452	100
Dummy	.500	.5025	100

Correlations

		AT Proxy	Dummy
Pearson Correlation	AT Proxy	1.000	.616
	Dummy	.616	1.000
Sig. (1-tailed)	AT Proxy	.	.000
	Dummy	.000	.
N	AT Proxy	100	100
	Dummy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Dummy[b]	.	Enter

a. Dependent Variable: AT Proxy

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.616[a]	.379	.373	9.6745525	.652

a. Predictors: (Constant), Dummy

b. Dependent Variable: AT Proxy

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5608.699	1	5608.699	59.924	.000[b]
	Residual	9172.503	98	93.597		
	Total	14781.202	99			

a. Dependent Variable: AT Proxy

b. Predictors: (Constant), Dummy

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Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
1 (Constant)	73.300	1.368		53.574	.000			
Dummy	14.978	1.935	.616	7.741	.000	.616	.616	.616

a. Dependent Variable: AT Proxy

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	73.299660	88.277908	80.788782	7.5268536	100
Residual	-29.7035122	24.0845108	.0000000	9.6255671	100
Std. Predicted Value	-.995	.995	.000	1.000	100
Std. Residual	-3.070	2.489	.000	.995	100

a. Dependent Variable: AT Proxy

Charts
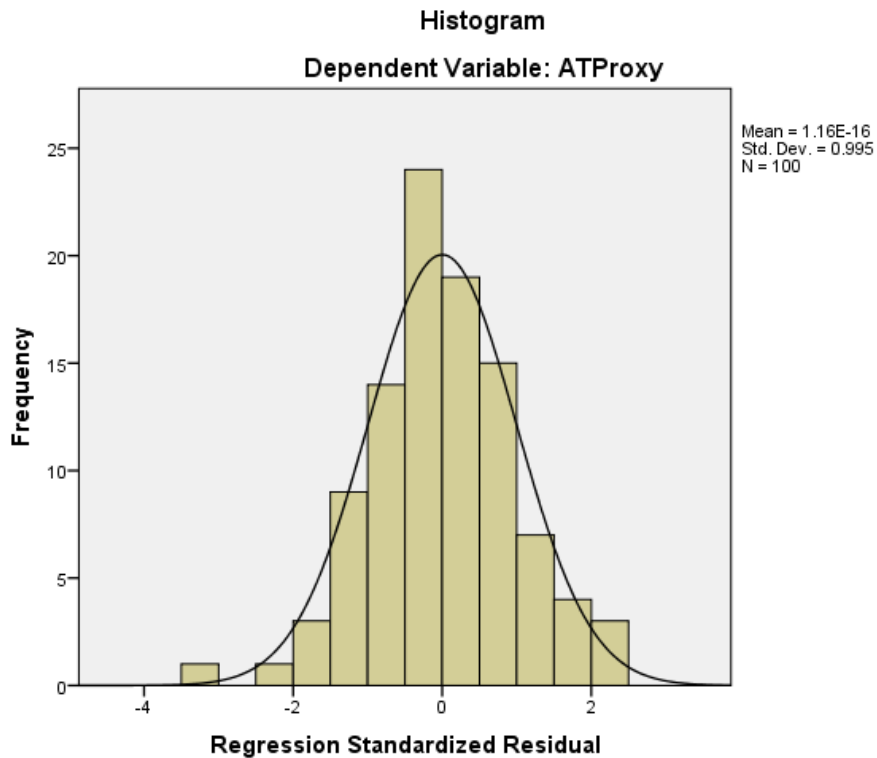
Histogram
Dependent Variable: ATProxy

Mean = 1.16E-16
Std. Dev. = 0.995
N = 100

105

Normal P-P Plot of Regression Standardized Residual
Dependent Variable: ATProxy
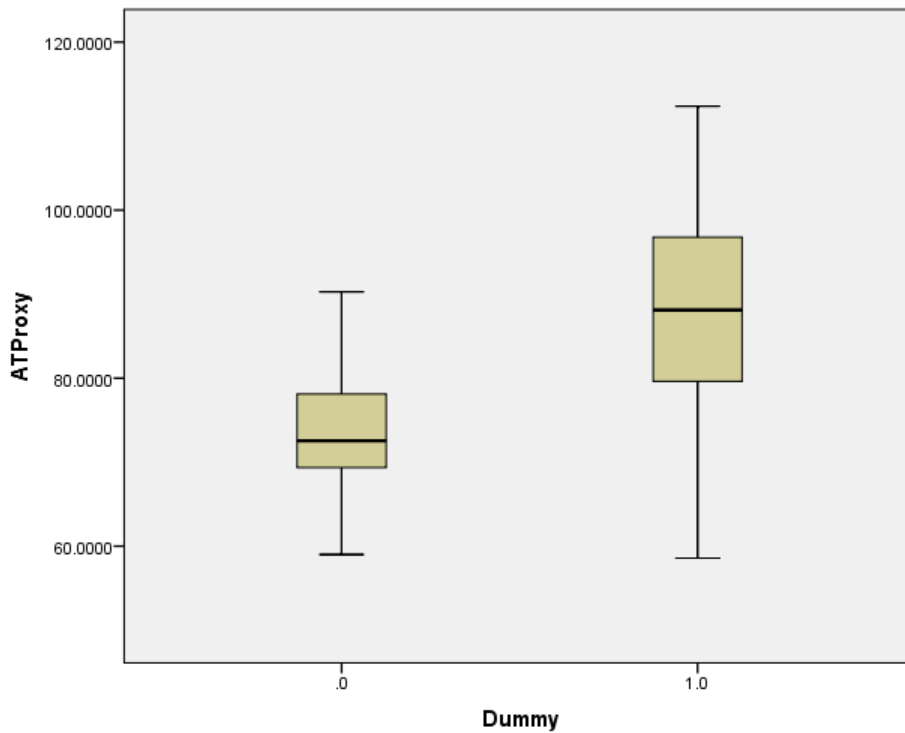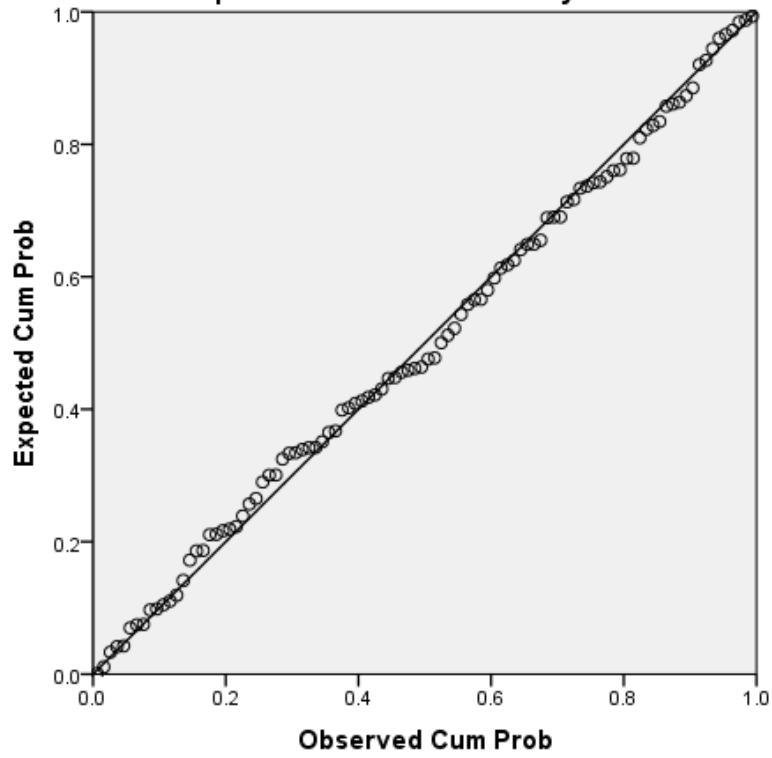
Appendix C - Liquidity Measures Correlation Matrix

Correlations

		Stock Turnover Ratio	Proportional Bid-Ask Spread	Price Impact Ratio	Zero Return Measure
Stock Turnover Ratio	Pearson Correlation	1	.283[**]	-.547[**]	.038
	Sig. (2-tailed)		.004	.000	.709
Proportional Bid-Ask Spread	Pearson Correlation	.283[**]	1	.331[**]	.027
	Sig. (2-tailed)	.004		.001	.786
Price Impact Ratio	Pearson Correlation	-.547[**]	.331[**]	1	-.024
	Sig. (2-tailed)	.000	.001		.809
Zero Return Measure	Pearson Correlation	.038	.027	-.024	1
	Sig. (2-tailed)	.709	.786	.809	

**. Correlation is significant at the 0.01 level (2-tailed).

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Appendix D - Statistical Output. Hypothesis 2: AT effect on Proportional Bid-Ask Spread (Liquidity Measure)

Descriptive Statistics

	Mean	Std. Deviation	N
Pspread	.121230	.0268944	100
AT Proxy	80.788782	12.2190452	100

Correlations

		Pspread	AT Proxy
Pearson Correlation	Pspread	1.000	-.078
	AT Proxy	-.078	1.000
Sig. (1-tailed)	Pspread	.	.220
	AT Proxy	.220	.
N	Pspread	100	100
	AT Proxy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	AT Proxy[b]	.	Enter

a. Dependent Variable: Pspread

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.078[a]	.006	-.004	.0269485	.506

a. Predictors: (Constant), AT Proxy

b. Dependent Variable: Pspread

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.603	.439[b]
	Residual	.071	98	.001		
	Total	.072	99			

a. Dependent Variable: Pspread

b. Predictors: (Constant), AT Proxy

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.135	.018		7.462	.000			
	AT Proxy	.000	.000	-.078	-.776	.439	-.078	-.078	-.078

a. Dependent Variable: Pspread

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.115796	.125054	.121230	.0021030	100
Residual	-.0351996	.1029202	.0000000	.0268121	100
Std. Predicted Value	-2.584	1.818	.000	1.000	100
Std. Residual	-1.306	3.819	.000	.995	100

a. Dependent Variable: Pspread

Charts

Histogram
Dependent Variable: Pspread

Mean = -8.05E-16
Std. Dev. = 0.995
N = 100

109
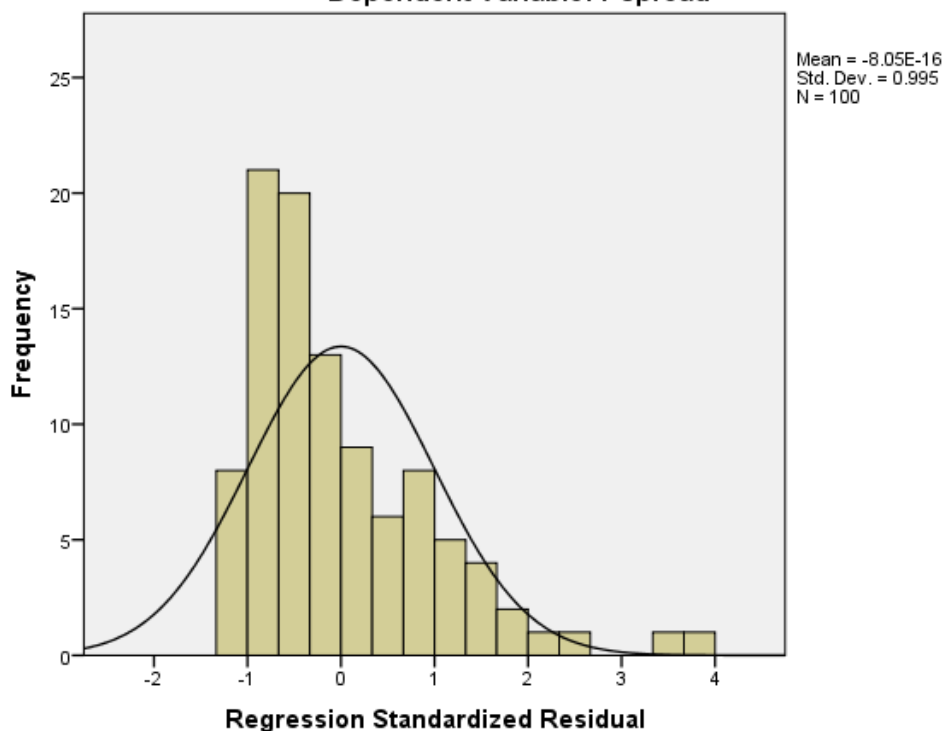
Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Pspread
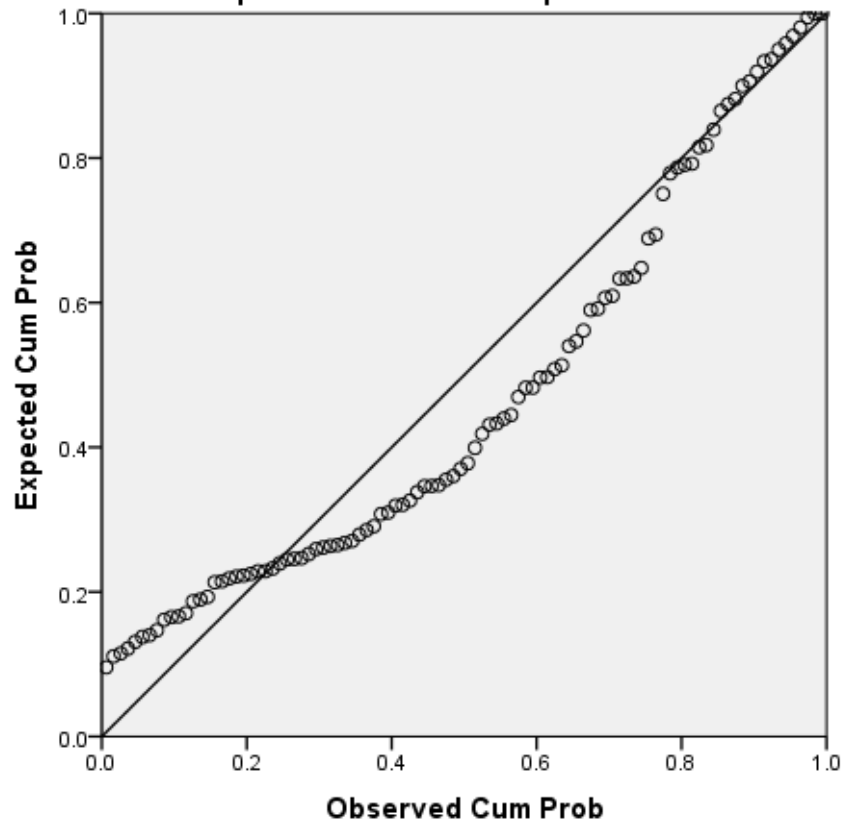
Appendix E - Statistical Output. Hypothesis 3: AT effect on Stock Turnover Ratio (Liquidity Measure)

Descriptive Statistics

	Mean	Std. Deviation	N
StockTurn	.127932	.0261659	100
AT Proxy	80.788782	12.2190452	100

Correlations

		StockTurn	AT Proxy
Pearson Correlation	StockTurn	1.000	.066
	AT Proxy	.066	1.000
Sig. (1-tailed)	StockTurn	.	.258
	AT Proxy	.258	.
N	StockTurn	100	100
	AT Proxy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	ATProxy[b]	.	Enter

a. Dependent Variable: StockTurn

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.066[a]	.004	-.006	.0262421	1.218

a. Predictors: (Constant), AT Proxy

b. Dependent Variable: StockTurn

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.426	.516[b]
	Residual	.067	98	.001		
	Total	.068	99			

a. Dependent Variable: StockTurn

b. Predictors: (Constant), AT Proxy

111

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
1 (Constant)	.117	.018		6.610	.000			
AT Proxy	.000	.000	.066	.652	.516	.066	.066	.066

a. Dependent Variable: StockTurn

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.124804	.132377	.127932	.0017205	100
Residual	-.0695831	.0928434	.0000000	.0261093	100
Std. Predicted Value	-1.818	2.584	.000	1.000	100
Std. Residual	-2.652	3.538	.000	.995	100

a. Dependent Variable: StockTurn

Charts

Histogram
Dependent Variable: StockTurn
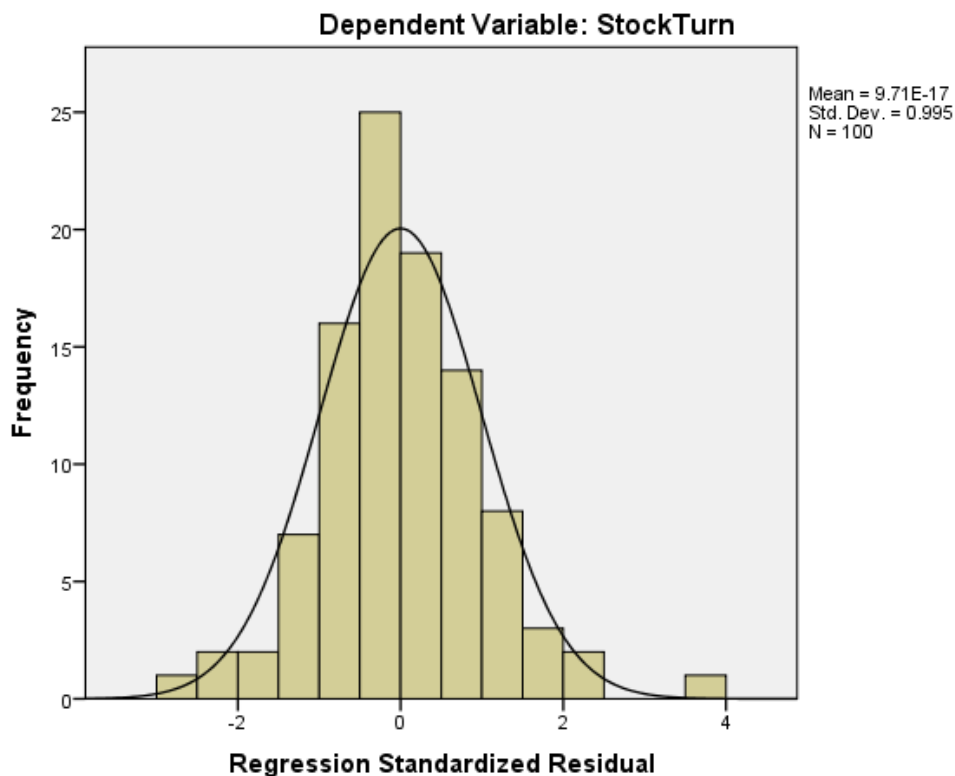
Mean = 9.71E-17
Std. Dev. = 0.995
N = 100

112

Normal P-P Plot of Regression Standardized Residual

Dependent Variable: StockTurn

113
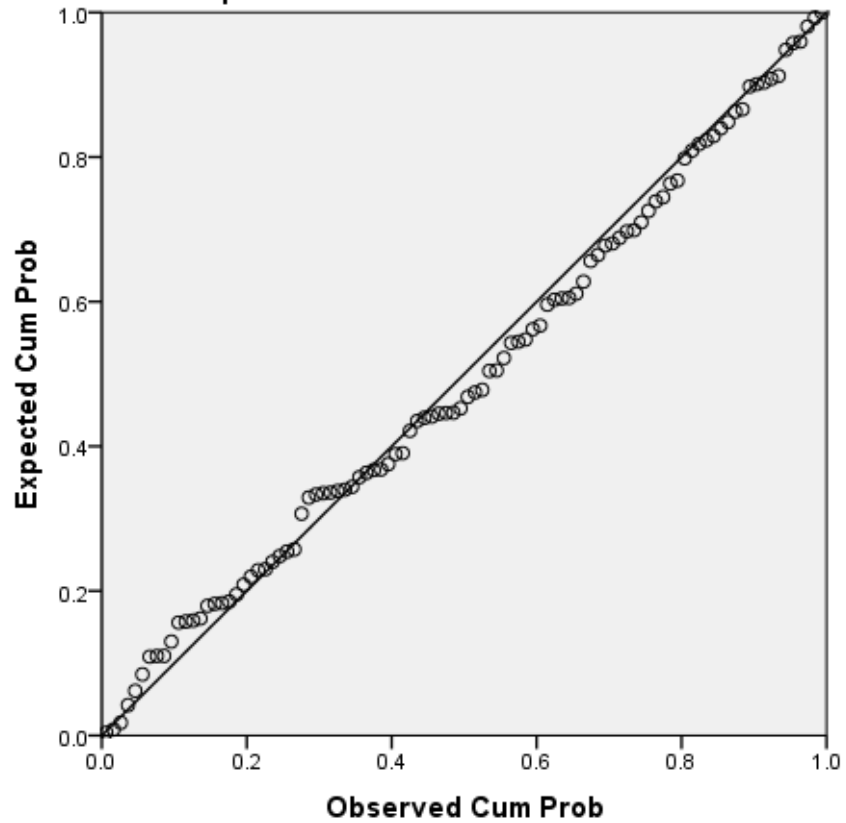
Appendix F - Statistical Output. Hypothesis 4: AT effect on Price Impact Ratio (Liquidity Measure)

Descriptive Statistics

	Mean	Std. Deviation	N
Pimpact	.007713	.0029627	100
AT Proxy	80.788782	12.2190452	100

Correlations

		Pimpact	AT Proxy
Pearson Correlation	Pimpact	1.000	-.165
	AT Proxy	-.165	1.000
Sig. (1-tailed)	Pimpact	.	.050
	AT Proxy	.050	.
N	Pimpact	100	100
	AT Proxy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	AT Proxy[b]	.	Enter

a. Dependent Variable: Pimpact

b. All requested variables entered.

Model Summary[b]

| Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.165[a]	.027	.017	.0029367	1.152

a. Predictors: (Constant), AT Proxy

b. Dependent Variable: Pimpact

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	2.759	.100[b]
	Residual	.001	98	.000		
	Total	.001	99			

a. Dependent Variable: Pimpact

b. Predictors: (Constant), AT Proxy

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Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.011	.002		5.551	.000			
	AT Proxy	-4.012E-005	.000	-.165	-1.661	.100	-.165	-.165	-.165

a. Dependent Variable: Pimpact

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.006446	.008604	.007713	.0004903	100
Residual	-.0044053	.0144179	.0000000	.0029219	100
Std. Predicted Value	-2.584	1.818	.000	1.000	100
Std. Residual	-1.500	4.910	.000	.995	100

a. Dependent Variable: Pimpact

Charts

Histogram

Dependent Variable: Pimpact

Mean = -1.38E-16
Std. Dev. = 0.995
N = 100

115
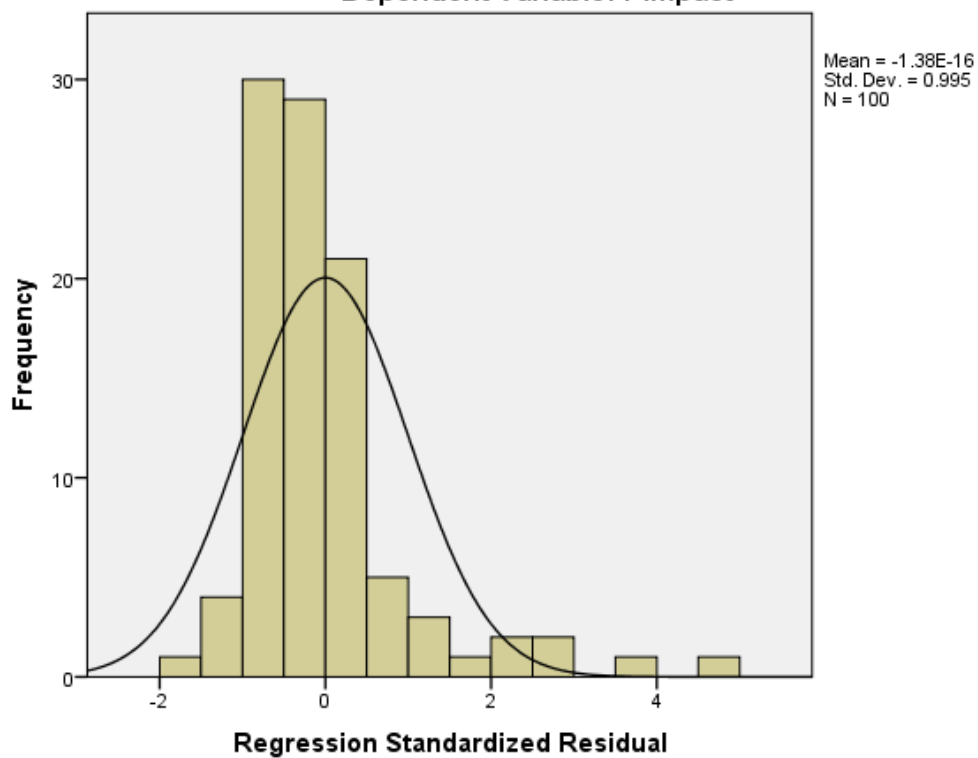
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Pimpact
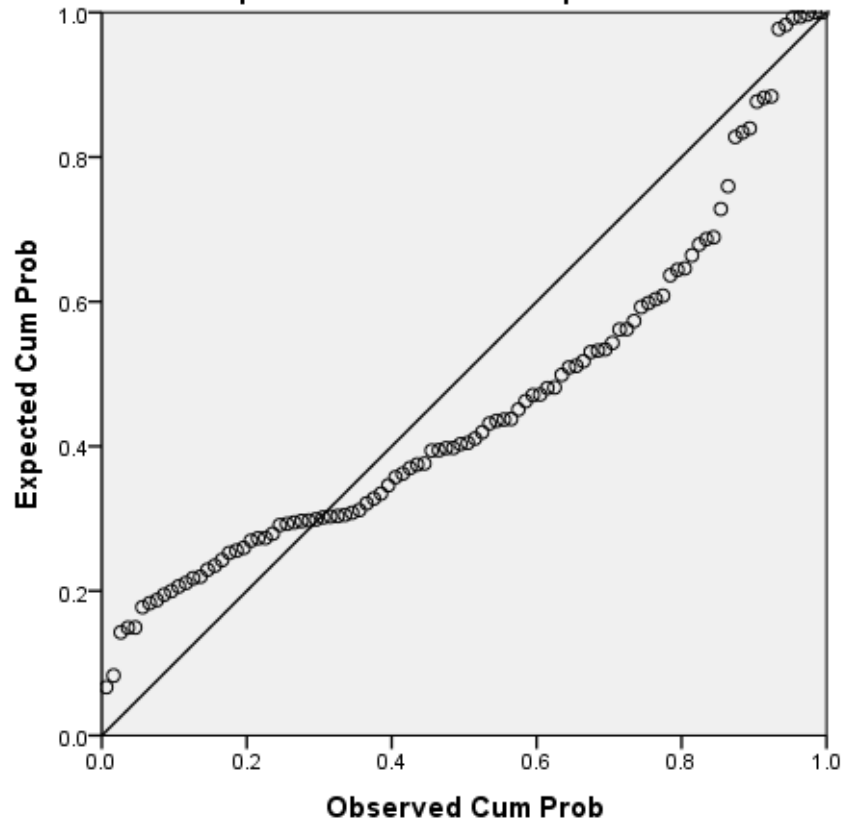
Appendix G - Statistical Output. Hypothesis 5: AT effect on Zero Return Measure (Liquidity Measure)

Descriptive Statistics

	Mean	Std. Deviation	N
Zero	.984642	.0094212	100
AT Proxy	80.788782	12.2190452	100

Correlations

		Zero	AT Proxy
Pearson Correlation	Zero	1.000	.215
	AT Proxy	.215	1.000
Sig. (1-tailed)	Zero	.	.016
	AT Proxy	.016	.
N	Zero	100	100
	AT Proxy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	AT Proxy[b]	.	Enter

a. Dependent Variable: Zero

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.215[a]	.046	.036	.0092481	1.847

a. Predictors: (Constant), AT Proxy

b. Dependent Variable: Zero

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	4.740	.032[b]
	Residual	.008	98	.000		
	Total	.009	99			

a. Dependent Variable: Zero

b. Predictors: (Constant), AT Proxy

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Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	.971	.006		156.288	.000			
	AT Proxy	.000	.000	.215	2.177	.032	.215	.215	.215

a. Dependent Variable: Zero

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.980963	.989872	.984642	.0020237	100
Residual	-.0364311	.0166883	.0000000	.0092013	100
Std. Predicted Value	-1.818	2.584	.000	1.000	100
Std. Residual	-3.939	1.805	.000	.995	100

a. Dependent Variable: Zero

Charts

Histogram

Dependent Variable: Zero

Mean = 8.81E-14
Std. Dev. = 0.995
N = 100

118
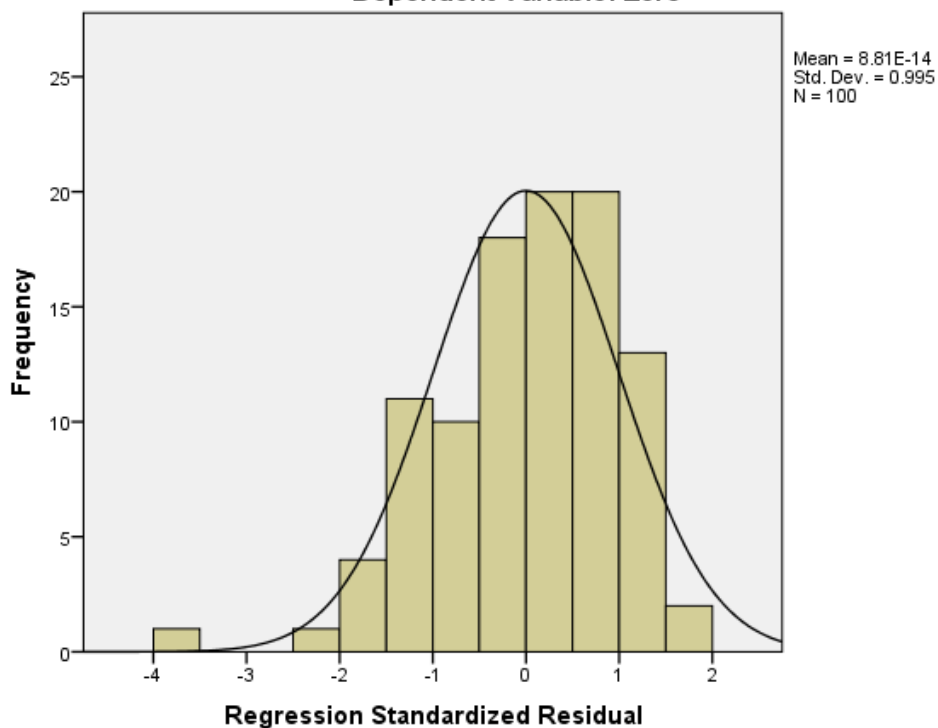
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Zero

Appendix H - Statistical Output. Extra Content: AT effect on volatility.

Descriptive Statistics

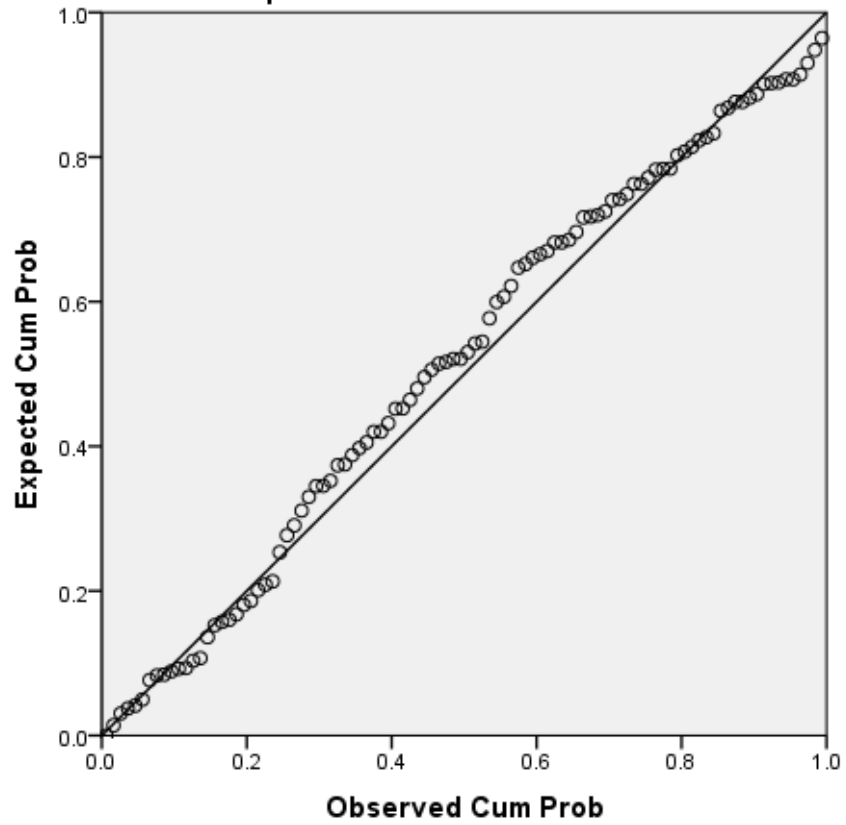|	Mean	Std. Deviation	N
Volatility	127.359928781541610	28.391691281628690	100
AT Proxy	80.788782	12.2190452	100

Correlations

		Volatility	AT Proxy
Pearson Correlation	Volatility	1.000	.422
	AT Proxy	.422	1.000
Sig. (1-tailed)	Volatility	.	.000
	AT Proxy	.000	.
N	Volatility	100	100
	ATProxy	100	100

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	ATProxy^b	.	Enter

a. Dependent Variable: Volatility

b. All requested variables entered.

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.422^a	.178	.170	25.871498990278490	1.405

a. Predictors: (Constant), ATProxy

b. Dependent Variable: Volatility

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14207.948	1	14207.948	21.227	.000^b
	Residual	65594.777	98	669.334		
	Total	79802.725	99			

a. Dependent Variable: Volatility

120

b. Predictors: (Constant), ATProxy

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	48.153	17.385		2.770	.007			
	ATProxy	.980	.213	.422	4.607	.000	.422	.422	.422

a. Dependent Variable: Volatility

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	105.58056640625	158.315261840820430	127.359928781541630	11.979759094772495	100
Residual	-39.988716125488	121.94240570068	-.000000000000126	25.740503216963850	100
Std. Predicted Value	-1.818	2.584	.000	1.000	100
Std. Residual	-1.546	4.713	.000	.995	100

a. Dependent Variable: Volatility

Charts

Histogram

Dependent Variable: Volatility

Mean = -1.09E-15
Std. Dev. = 0.995
N = 100

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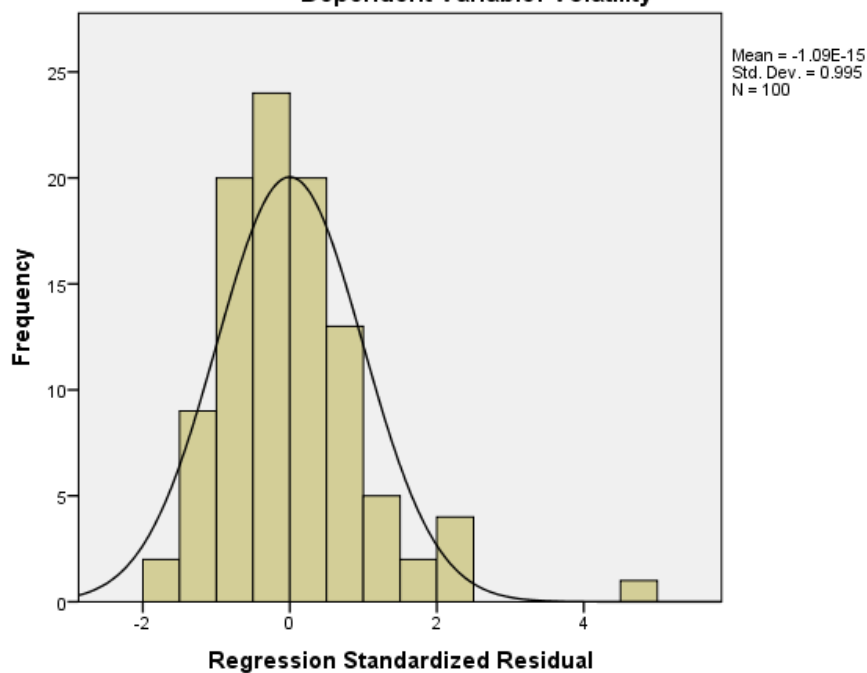
Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Volatility
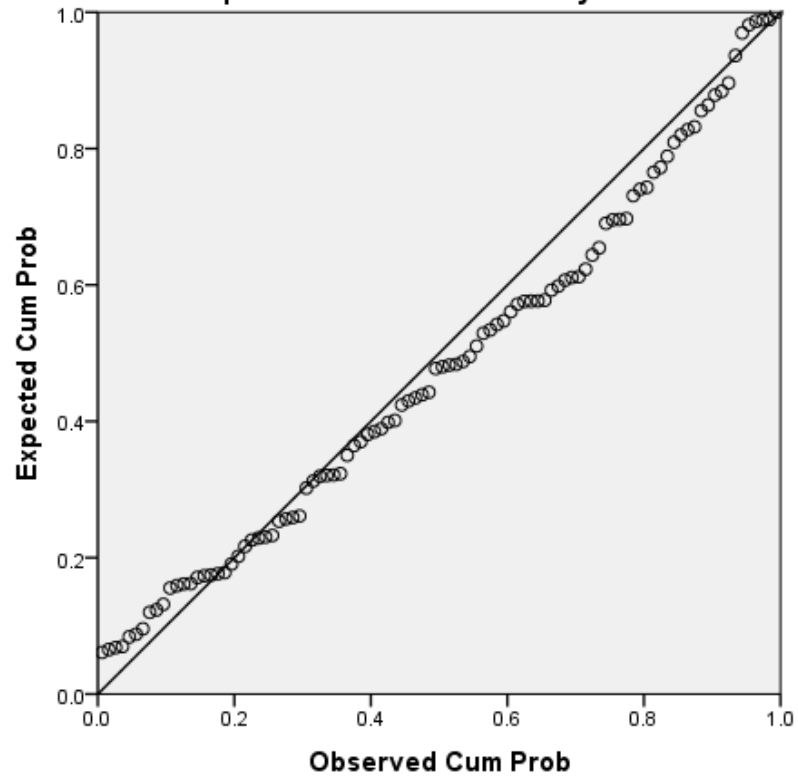
Appendix I - Statistical Output. Extra Content: AT Effect on the Average Trade Size

Descriptive Statistics

	Mean	Std. Deviation	N
Tradesize	115766.3587883723000	15607.41764982077000	100
AT Proxy	80.788782	12.2190452	100

Correlations

		Tradesize	AT Proxy
Pearson Correlation	Tradesize	1.000	-.749
	AT Proxy	-.749	1.000
Sig. (1-tailed)	Tradesize	.	.000
	AT Proxy	.000	.
N	Tradesize	100	100
	AT Proxy	100	100

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	AT Proxy[b]	.	Enter

a. Dependent Variable: Tradesize

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.749[a]	.561	.556	10398.83241596435300	1.173

a. Predictors: (Constant), AT Proxy

b. Dependent Variable: Tradesize

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13518256953.597	1	13518256953.597	125.012	.000[b]
	Residual	10597300130.300	98	108135715.615		
	Total	24115557083.898	99			

a. Dependent Variable: Tradesize

b. Predictors: (Constant), AT Proxy

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	193026.685	6987.851		27.623	.000			
	AT Proxy	-956.325	85.532	-.749	-11.181	.000	-.749	-.749	-.749

a. Dependent Variable: Tradesize

Residuals Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	85571.703125000	137010.53125000	115766.35878837	11685.377616335	100
Residual	-26637.910156250	37822.855468750	.00000000001844	10346.179761612	100
Std. Predicted Value	-2.584	1.818	.000	1.000	100
Std. Residual	-2.562	3.637	.000	.995	100

a. Dependent Variable: Tradesize

Charts

Histogram
Dependent Variable: Tradesize

Mean = 1.79E-15
Std. Dev. = 0.995
N = 100

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Normal P-P Plot of Regression Standardized Residual

Dependent Variable: Tradesize