Commencement of Electronic Trading: Impact on Liquidity, Price Discovery and Market Efficiency - Australian Evidence from Sydney Futures Exchange

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ABSTRACT

Using mixture of distributions hypothesis, we evaluate the liquidity of the Sydney Futures Exchange with an analysis of 'at the money' share price index (SPI) call options and SPI futures contracts after the introduction of electronic trading on 15 November 1999. The results show that during the proximate period up to beginning August 2000 'at the money' SPI options were more liquid in times of high volatility after the SFE became automated. But the SPI futures are less liquid in times of medium to low market volatility after the automation.

An examination of the price discovery process before and after automation was also incorporated into this study in testing market efficiency. Under this assumption the trading prices in the Australian Stock Exchange (ASX) and Sydney Futures Exchange (SFE) should have a long-run cointegrating relationship. The results confirm a cointegrating relationship between the two markets before and after the introduction of electronic trading supporting the semi-strong market efficiency.

Our findings also indicate presence of a bi-directional lead–lag relationship between the SPI futures price and the All Ordinaries Index price before and after the introduction of electronic trading. This suggests that the electronic trading structure does not seem to greatly enhance the price discovery price of the SFE.

Key words: Futures and options trading, derivatives, electronic trading, cointegration

JEL Classification: G14**,** G19, C51

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1.0 Introduction

On the 28 October 1999, the Floor Members of the Sydney Futures Exchange (SFE) voted to transfer SFE's floor based futures and options contracts to the electronic trading system. On March 4, 1999, the SPI ceased floor trading and became screen traded. Later, on Friday, November 12, 1999 the remainder of the floor trading ceased, and on Monday, November 15, 1999 the Sydney Futures Exchange became a completely automated system, with all trading conducted by SYCOM IV.

The Australian Stock Exchange (ASX) became completely automated in October 1990 with its electronic trading system, SEATS (ASX Website, 2000). Now that the spot (ASX) and derivative markets (SFE) have similar trading structures, a unique opportunity is provided to empirically examine the whether automation has influenced the derivative markets operational, informational and market efficiency in comparison to the ASX.

Completely automated trading structures have been introduced at various futures exchanges around the world. Despite the efficiency gains that accompany such automation, there is a reluctance to move away from open outcry trading system, citing early evidence that open outcry exchanges were more liquid than electronic exchanges. However, more recent studies have suggested that electronic trading is superior to open outcry in many respects including liquidity.

This study provides evidence on whether the claims of Sydney Futures Exchange on the advantages of the new structure are in fact true. The major advantage perceived is that liquidity and the price discovery process of the market will be enhanced due to the lower costs of trading, faster trade execution, cleaner information dissemination, and greater transparency with respect to prices and quotes.

The outline of the study is as follows. Section 2 provides a selected literature review while identifying the four research propositions. Sample design, model and statistical procedures are given in Section 3 while empirical results are analysed in Section 4. Concluding remarks are given in Section 5.

2.0 Review of Literature

2.1 Dynamics of a Changing Market Structure

Since the late 1980's the rapid advancements in informational technology have transformed financial markets. The improved technology has not only enhanced the computing and modelling skills used by professional investors in financial markets, but also has been a catalyst for developments and change in the market structures. Electronic screens in securities exchanges are replacing the traditional open outcry floor trading structures with an automated trading system (Kofman and Moser, 1997). This change reflects the notable sentiment in demands by market participants, based on issues centred on increasing operational efficiency[1] while maintaining the market's ability to equal or greater informational efficiency[2]. An automated system claims to have benefits for market participants by way of lower infrastructure costs, improved price transparency, superior platform and listing for new products, global distribution, and improvements in speed of trade execution.

With the increasing implementation of automated trading structures, the important review by Massimb and Phelps (1994) raised a number of contentious issues regarding the benefits and shortcomings of electronic trading systems. At face value the issues relating to automation appear straightforward. However, according to Massimb and Phelps (1994) automating an existing trading floor structure can raise doubts about the possible benefits of the new structure. They have raised the issue that the dynamics of the open outcry system is not effortlessly captured or supported by the electronic trading structure, and that the introduction of electronic trading forces a trade-off between the advantages of either system. Massimb and Phelps (1994, p. 39) suggest that:

> "Exchanges, regulators and investors evaluating the relative merits of open-outcry and electronic matching should note, however, that the trading environment and the trade matching algorithms embedded in electronic matching fail to capture those features of open outcry that account for its success and liquidity."

Automation does offer and create operational efficiencies (see Ates and Wang 2005), although it can be traded off against the liquidity from the trading floor system involving open outcry. The liquidity depletion is derived from the apparent impact of trading transparency that the 'local traders' require to fulfil their perceived role in the market, which is to provide liquidity.

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[1] Massimb and Phelps (1994) expressed operational efficiency as the market's ability to lower costs of trading, and its execution speed of orders between the buyer and seller. See Ates and Wang (2005) for latest evidence on operational efficiency in US futures market.

[2] Informational efficiency means that all traders have equal access to all public information and that the information is quickly reflected in trading prices (Tsang, 1999).

2.2 Liquidity

The changeover from an open outcry structure to an electronic trading structure has in the past altered the liquidity of futures markets. Study by Massimb and Phelps (1994) amongst others argues that the open outcry structure is more liquid. The empirical results presented by Shyy and Lee (1996) also show higher liquidity in an open outcry structure. However, the study by Pirrong (1996) supports the view that automation increases liquidity within the market.

Technology is progressing rapidly and the markets are becoming increasingly more complex. Most securities markets have begun to shift from the traditional trading floors to automated trading systems to cope with the increase in volume and to lower transaction costs, with the added bonuses of allegedly reduced human error and greater liquidity (Massimb and Phelps, 1994). Recently Bortoli, Frino and Jarnecic (2004) have shown that lower brokerage commissions have resulted from electronic trading in Sydney Futures Exchange.

The successful transition to an automated trading system must carry across the key dynamics and attributes from the open outcry trading system (Massimb and Phelps, 1994). When considered along with the added benefits of lower infrastructure costs, more efficient transaction pricing, automation seems very appealing. However, Pirrong (1996) attributes the success of a trading structure to the market's ability to generate and maintain liquidity.

2.3 Assumptions under the mixture of Distributions Hypotheses

The study by Frino, McInish and Toner (1997) found that the liquidity of automated systems decreased during times of high volatility, compared to the open floor traded system. The mixture of distributions hypothesis (MDH) developed by Clark (1973), Epps and Epps (1976), and Tauchen and Pitts (1983) provides a theoretical framework to explain that returns and trading volume are driven by the same underlying latent news arrival, or information-flow. The arrival of unexpected good news results in a price increase, whereas the arrival of bad news results in a price decrease. Both of these events are accompanied by above average trading activity in the market as it adjusts to new equilibrium. Accordingly, the absolute price change, and trading volume should be positively correlated. This is known as the mixture of distributions hypotheses.

Copeland (1976) states that the trading volume can be used as a proxy of information arrival. A theoretical explanation of the sequential information flow between stock and option markets was provided by Copeland. The price-volume relationship was also found to have significant implications for the entire futures market as the absolute change in price is reflected by an increase in trading volume (Karpoff, 1987). Thus, days with large volumes suggest high market volatility, and days with low volume imply small market volatility. Therefore, if the market index and market index futures are essentially reacting to the same information, as explained by the sequential flow of information (Copeland, 1976), the markets should both adjust to new information, and correspondingly affect the trading volume levels (Cornell, 1981; Martell and Wolf, 1985).

Prior research by Brailsford (1996) investigated the empirical relationship between trading volume, returns and volatility on the All Ordinaries Index on the Australian Stock Exchange (ASX) from 24 April 1989 to 31 December 1994. Brailsford (1996) found support for the mixture of distributions hypothesis by explaining how returns are generated, and implications of the MDH for inferring return behaviour (non-normality in returns through the arrival of information) from trading volume.

2.4 Options data volume as a proxy for liquidity

The following discussion on option data attempts to establish a link with the MDH approach and further justify the utilization of the liquidity ratio analysis. Option data can be incorporated into the study of liquidity by using a technique developed by Rubinstein (1994) in that the strike prices of the options contracts can be grouped into portfolios. The portfolios are ranked in terms of moneyness that in turn can be used to assess the liquidity of the option contract traded. Moneyness is a term used to describe the relative closeness of the strike price to the stock price. The advantage of using this technique is that it allows simplification of the variable to be tested in the data set, to provide a more in depth analysis. This approach will be followed in this study. Each portfolio will be sorted by the strike price: stock price ratio to determine moneyness, and then further sorted by the option contracts based on time to expiration. This approach will provide an insight into volume liquidity in the option market since the automation of the SFE.

Anthony (1988) investigates causal effects of the sequential flow of information between the stock market and option market using their trade volumes based on the assumptions of the mixture of distributions hypothesis discussed earlier. Daily volume data of 25 company's call options for the period January 1982 through June 1983 listed on the CBOE were used. Anthony's study is useful as it suggests that liquidity is generated by information arrival and thus can be identified through volume changes. The informational effects can be held constant, as it is incorporated into the prices of both markets, and therefore ratio analysis as discussed earlier can provide an insight into the effects of the automation of the SFE.

Jarnecic (1999) also investigates the lead-lag relationship of intraday data between trading volumes of stocks and stock options of the ASX and ASX options (note that these ASX options are not traded at the SFE). The results indicate that any lead relationship was found to have been eliminated when frequent trading occurred in both markets. Jarnecic's study appears to highlight the overstating of the lead-lag relationship through the examination of intra-day day data[3]. The use of daily data as in this investigation will not be prone to such results.

In this study, liquidity ratios will be constructed from the volume data of the All Ordinaries Index, and the share price index (SPI) futures and option contracts. These ratios will be used to investigate the liquidity of the SFE before and after automation. The mixture of distributions hypothesis will be used as a theoretical explanation to categorize the ratios into volume groups based on their size. Thus, each group corresponds to a level of market volatility and therefore can be used to analyse whether the futures and options contracts increase or decrease in liquidity in periods of high and low volatility. It is likely that there will be no change in the liquidity ratios. This is based on the assumption that the automation transition in the SFE has been conducted carefully to maintain the existing dynamics of the old floor structure and incorporate them with the benefits of automation. It should be noted that Australian stock and futures market are small, when compared to other larger international markets that have substantially larger trading volumes. Based on the above discussion the following research proposition is drawn.

> **Research Proposition 1:** *The liquidity and liquidity ratio will change after the SFE became an electronic trading system.*

2.5 Price discovery and operational efficiency of a market structure

Price discovery is the differential reaction of the different markets to new information, and the rate at which the new information is incorporated into price. Fama's (1970) semi-strong

[3] Overstatement of the lead-lag relationship will be discussed later in this paper.

form[4] of the 'efficient market hypothesis' (EMH) states that the price discovery process must be very small so as to prevent earning abnormal returns. Therefore the market structure is important, as it must optimise the price discovery process between markets to provide no significant excess returns to market participants (O'Hara, 1995).

Market efficiency[5] also depends upon the notion of operational efficiency. This is the market's ability to provide liquidity, speed of execution, and minimize transactional costs. The concepts of price discovery and operational efficiency should complement each other according to Freund, Larrain and Pagano (1997). Their study on the Toronto Stock Exchange (TSE) measured the speed of transmission of daily and monthly returns data of 25 stocks for the period of January 1976 to March 1981. It was the time period during which the TSE introduced the new electronic trading system. This change in trading system allowed Freund, Larrain and Pagano (1997) to determine any change in market efficiency resulting from a change in operational structure efficiency.

In a recent study on France, Germany, South Korea and the UK Copeland, Lam and Jones (2004) rejected the random walk hypothesis for both open-outcry and electronic trading systems. Their results suggest that there has been no increase in efficiency as a result of the introduction of electronic trading.

2.6 Cointegration

As stated earlier, the objective of the present study involves the investigation of market efficiency before and after automation of the Sydney Futures Exchange (SFE). In order to provide an insight on the pricing of information in regard to the futures and spot market and determine the existence of any change in the relationship between the two markets from automation, cointegration methodology can be used. The cointegration approach can be used to empirically investigate the relationship between the spot price and futures price from their corresponding markets to investigate the predictive price effect of the quoted futures contract to the underlying asset price effect.

Mananyi and Struthers (1997) examined the semi-strong form of the efficient market hypothesis (EMH) of the monthly spot and futures cocoa prices traded on the London Futures and Options Exchange from the period of January 1985 to December 1991. Using the cointegration methodology the study found that behaviour of cocoa prices was inconsistent

[4] Fama's (1970) has identified three levels of market efficiency. Semi-strong form of the 'efficient market hypothesis' states that prices reflect all publicly available information.

with the semi-strong form of EMH. It could not find evidence that the spot and futures prices were cointegrated together in a long-term equilibrium relationship in the Cocoa markets. Mananyi and Struthers (1997) attributed these inconsistent findings to irrationality associated with the complex institutional arrangements characterizing the type of futures traded.

Kempf and Korn (1998) examined the intra-day minute-by-minute integration between the German stock index DAX and DAX futures from June 1995 to March 1996. The importance of their study lies in the fact that the DAX was being traded simultaneously on the open outcry trading system and screen traded system. The investigation allowed the examination of the relationship between spot and futures markets for different spot trading systems. It was found that the markets are more closely integrated when both the DAX Index and DAX futures are screen traded, however, the performance of both systems in time of high and low trading activity does not seem to affect either system. Kempf and Korn (1998) attribute the higher degree of integration to the delayed information flow and order execution lags on the floor-traded markets.

Daily price data were used by Ackert and Racine (1999) to examine whether equity spot and future markets were cointegrated. From this they used data on the Standard and Poor's S&P 500 index and associated futures contract closing prices from 4 January 1988 to 30 June 1995. It was concluded that Standard and Poor's S&P 500 index and futures price and interest rate are cointegrated, which is consistent with the view that no-arbitrage assumption is reasonable in equity markets.

Groenewold (1997) reports the results of various tests of the EMH using daily data, (as used in this study) of the Australian Statex Actuaries Price Index, Statex Actuaries Accumulation Index, and the All Ordinaries Price and Accumulation Indexes, against New Zealand's NZSE-40 Index, and NZ Gross Index for the period of 1975 through to 1992. The study tests semi-strong form efficiency using Johansen cointegration tests, and also tests the two market's lead-lag relationship by testing with Granger causality. The cointegration and lead-lag methodology (as used in this study) found that indexes across regions were not cointegrated and also not Granger caused over the period examined.

Turkington and Walsh (1999) used intraday frequency data for the period of January through to December 1995 to examine the Australian All Ordinaries index and the SPI (Share Price Index) futures, to investigate the impact of market structure on trading through

[5] Market efficiency is discussed in detail in the following section.

cointegration and causality. They found that over the sample period the market was cointegrated and that causality was bi-directional.

The previous Australian studies are important to this investigation for two reasons. Firstly, both studies: those of Groenewold, and the Turkington and Walsh used similar methodologies that provide an insight to the expected results of the pre-automation period examined. Secondly, the present study plans to examine whether in fact a change in the trading structure will change the cointegrating and causal relationships found in the previous studies. Based on the literature reviewed here the following research propositions can be formulated.

> **Research Proposition 2:** *The share price index (SPI) is cointegrated with the All Ordinaries Index six months before the introduction of electronic screen trading at the Sydney Futures Exchange.*

> **Research Proposition 3:** *The share price index (SPI) is co-integrated with the All Ordinaries Index six months after the introduction of electronic screen trading at the Sydney Futures Exchange.*

The Lead-Lag Relationship

The lead-lag is a term used to describe the relationship between two markets. The relationship shows the flow of information being simultaneously and unbiasedly incorporating into each markets prices (Fama, 1970). If the price in each market incorporates the new information at different intervals of time, the market that does so in the quickest manner will appear to the lead the other.

A substantially debated stream of finance literature stems from the issue of price discovery and that markets are not semi-strong form efficient, as they do not simultaneously incorporate new public information into their prices (Grünbichler, Longstaff and Schwartz, 1994). As a result it is possible for one trading market structure to discover prices more rapidly than another type of trading structure. Does the open outcry floor trading structure or electronic screen trade structure provide faster price discovery, or create a lead-lag relationship?

There is significant, subsequent research investigating lead-lag relationships between asset and derivative markets. Much of the research by Grunbichler, Longstaff and Shwartz

(1994), Kofman and Moser (1997), and Turkington and Walsh (1999) have all examined stock indexes and the stock index futures from various markets from around the world to determine whether the operational efficiency has improved from a structural change in the market.

The data used by Brooks, Garrett and Hinich (1999) were daily returns for the FTSE 100 index and Index futures contracts in the UK for the period of January 1985 to December 1993, and the S&P 500 Index and Index futures contracts in the US for the period January 1983 to December 1993. They selected the daily data set as it would not be prone to overstate the lead-lag relationships that occur with intra-day data. The results showed that contrary to the use of traditional intra-day data and methodology, the periods where the futures market leads the cash market are few and far between. Any lead-lag relationship that is detected will not last long. They conclude that the results are consistent with the prediction of the standard cost-of carry model[6] and market efficiency.

The present study on trading structures in the SFE will use an approach similar to that in Brooks, Garret and Hinich (1999), to determine the lead-lag relationship of the S&P/ASX 200. Based on their model, data on the All Ordinaries Index and the share price index futures (SPI) in the SFE will be used to identify cross-correlations and bi-correlations. For this purpose daily data will be used.

It is likely that there will be no change in lead-lag relationship between the ASX and the SFE the new system was implemented gradually over a reasonable period of time (March to November 1999). This leads to the development of the research proposition:

> **Research Proposition 4:** *The electronic market lead-lag relationship will remain unchanged after the change from the trading floor system to the electronic trading system.*

3.0 Sample design

3.1 Data sources

The daily data for the period from January 2, 1998 to August 1, 2000 as required for the study has been collected from two sources. The event date is defined as 3 March 1999. The event date is the day upon which the SPI transferred from being floor traded to an automated electronic system. This event date should not to be confused with the full automation of the

[6] Cost of carry is the cost involved in storing an asset and interest lost on funds tied up therein.

system that occurred on November 15, 1999.The Sydney Futures Exchange data for the Share Price Index consisting of futures and call option contracts was downloaded from the Sydney future Exchanges website (http://www.sfe.com.au). The call option data has been used since call options in general, are traditionally more frequently traded and have greater depth of liquidity, as compared to put options. The historical daily data files downloaded from the SFE website are daily date labelled open, high, low, close prices, expiry, strike price and volume for night and day with settlement, open interest, risk and volatility for the SPI futures and options contracts.

The Australian Stock Exchange data was collected from the DataStream database that contained all the relevant data required for this research. The information required for the All Ordinaries Index was daily dated open, high, low, close price and volume. The secondary data used in the investigation, such as ratios, explained further on, were calculated from the primary data sources as discussed above.

As option data is utilised in the testing of hypotheses one and two, it has to be arranged properly as to achieve the best results. As option data have a large number of option contracts with differing strike prices traded at one time, the contracts must be organised into moneyness portfolios. As shown in Table 1 the contracts are organised into a ratio corresponding to the underlying spot index. This indicates the moneyness of the contract, and allows the strike prices of contracts to be simplified into five basic moneyness portfolios (Rubinstein, 1994). These being 'Far Out of The Money' (FOTM), 'Out of The Money' (OTM), 'At The Money' (ATM), 'In The Money' (ITM) and 'Far In The Money' (FITM).

Table 1.1 Portfolio Moneyness

	Striking Price Range				
Portfolios	FOTM	OTM	ATM	ITM	FITM
Ratio	>9%	9% to 3%	3% to -3%	-3% to -9%	<-9%

Source: Rubinstein (1994)

The option moneyness portfolios have classified the strike prices of the option contracts into groups relative to the spot index at that point in time. The option contracts have different dates to expiration. These have also been isolated into groups of expiration. The call option contracts with expirations of one month, two months, and three months will be investigated in this study. This is due to the fact that option contracts with dates to expiration outside this period (three months) were found to be showing highly inconsistent behaviour.

3.2 Methodology

The methodological approach is aimed at two aspects of the automation of the Sydney Futures Exchange. The first aspect is the analysis of the markets liquidity by analysis of the volume. The second aspect as discussed earlier is the price discovery process utilising cointegration and causality theories in examining these relationships between the Australian Stock Exchange and the Sydney Futures Exchange. The following section provides a discussion on variable specification, model and statistical procedures.

Model and Statistical Procedures

Liquidity

The core of this research centres on determining the effect of the structural change in trading at the SFE, and whether there has also been a change in liquidity. Measurements of the pre-automation group against the post-automation group can provide an indication to the liquidity effects over these two periods. To test the liquidity of the market the call option data will be based on moneyness portfolios, as was discussed earlier.

Data Organisation

As mentioned earlier the data will be organised into pre-automation and post-automation groups as done in the Freund, Larrain and Pagano (1997) study as it will provide sub-groups to compare against each other. Within these two groups the data will be further classified into portfolios of moneyness and expiration (Rubinstein, 1994). The option moneyness portfolios will be examined in full, with not only descriptive statistics, but also by investigating the mean contract size as per sample and per days traded. Analysis of variance will be carried out to test the difference of means through the moneyness portfolios along with the analysis under the assumptions of the MDH.

The mixture of distribution hypothesis (MDH) provides a theoretical assumption to explain why an absolute change in price occurs with the increase in volume, as both are related to the amount of information in the market. Therefore, if there is a large amount of information in the market (highly volatile), the price will accordingly fluctuate unbiasedly reflecting the true value, and therefore requires a proportional amount of trading volume to move the market to reach this equilibrium (Richardson and Smith, 1994). Therefore, the data will categorise the days by volume size as to represent market volatility. Thus days of high market volatility will be shown to have large volume size within the group, and the small volume days will represent low market volatility. This will allow an investigation of liquidity change to be measured at different stages of market volatility to determine whether the SFE has benefited from the automation of the open outcry trading floor to an electronic screen traded system.

Descriptive statistics

The comparison of the SPI futures contract and All Ordinaries Index for the daily volume will be initially based on an analysis of the descriptive statistics. This analysis will provide an insight into the nature of the All Ordinaries Index and futures contract variables. The ratio tests (described in detail below) will provide a more coherent and appropriate analysis of the liquidity change in the index and futures index across the sub-periods. Any liquidity change found from the ratio investigation will be considered more influential, than relying on the descriptive statistics results. Further insight will be provided by the ANOVA tests performed. MDH will be used (as discussed above) as a theoretical assumption to investigate differing market volatilities, by groups of volume size. This provides a unique methodology to analyse the liquidity of the market when it is highly volatile (large volume groups), and at low market volatility (small volume groups).

Ratio analysis

Ratio analysis is the second aspect to the investigation of liquidity change at the Sydney Futures Exchange. This is done by statistical analysis of a combination of ratios between the call option and futures index (daily and nightly) volumes, holding expiration to maturities constant, against the each other and against the daily index volumes. The method of calculation of the liquidity ratios is given in Appendix 1. A ratio of the futures volume to the spot volume will be calculated in two periods (pre-automation, post-automation) to determine a simple liquidity ratio. If the ratio increases or decreases after automation, this can be seen as signal of a change in overall liquidity resulting from automation at the SFE. The ratios will then be subjected to ANOVA tests to compare the means and determine whether there has been any significant results from the cross evaluation of the two periods.

ANOVA is a statistical method for determining the existence of differences among several population means. Using an ANOVA test assumes that independent random sampling for each of the *r* populations, and that the *r* populations are normally distributed, with means μ_i that may or may no be equal, but with equal variance σ^2. There null hypothesis for ANOVA test is that the mean of population one is equal to the mean of population two, with the alternate hypothesis stating that the population mean one does not equal population mean two.

Regression Analysis

Regression analysis aims to complete the investigation of liquidity to provide a concise statement concluding the advantages sought or lost in the introduction of electronic trading at the SFE. In regression analysis the dependent variables is the SPI futures to All Ordinaries Index ratio. The independent variables used are: the open interest, settlement price of the futures market, the 'at the money' (ATM) ratio, and the ATM volume. Dummy variables will be included to represent the pre and post period, along with dummy variables for the mixture of distribution groups representing descending volume size as a proxies of different levels of market volatility. This regression equation is as follows:

$$\begin{aligned} y &= \alpha + (\beta_1 In(OI)) + (\beta_2 In(SETT)) + (\beta_3 Dummy_1 Pre\_Post) \\ &+ (\beta_4 Dummy_2 VOL\_1) + (\beta_5 Dummy_3 VOL\_2) + (\beta_6 Dummy_4 VOL\_3) \\ &+ (\beta_7 Dummy_5 VOL\_4) + (\beta_8 Dummy_6 VOL\_5) + e_t \end{aligned} \quad (1)$$

where:

y = Share price index / All Ordinaries Index

OI = Open Interest

SETT = Settlement price of the share price index

$Dummy_1Pre\_Post$ = Dummy variable for the pre-automation and post-automation period (0 if it is the pre-automation period, and 1 if it is the post-automation period)

$Dummy_2VOL\_1$ = Dummy variable for the largest volume group (0 if it is group volume 1, and 0 otherwise).

$Dummy_3VOL\_2$ = Dummy variable for the second largest volume group (0 if it is group volume 2, and 0 otherwise).

$Dummy_4VOL\_3$ = Dummy variable for the third largest volume group (0 if it is group volume 3, and 0 otherwise).

Dummy$_5$*VOL_4* = Dummy variable for the fourth largest volume group (0 if it is group volume 4, and 0 otherwise).
Dummy$_6$*VOL_5* = Dummy variable for the fifth largest volume group (0 if it is group volume 5, and 0 otherwise).
e_t = Random error term.

These results found from the regression analysis can be compared with the ANOVA results. This concludes the methodology used in this study to investigate the liquidity of the SFE before and after the introduction of electronic trading. The following section explains the methodologies used to investigate the price discovery process of the Sydney Futures Exchange.

3.3 Cointegration

Unit Root Tests

Following the theory of non-stationary time series developed by Engle and Granger (1987) cointegration of a linear combination of two or more series can occur. Two unit root tests will be conducted in this study to determine whether the time series is stationary or non-stationary. The first test is the Augmented Dickey Fuller (ADF) test; with the second test being the Phillip-Perron (PP) test. The null hypothesis being tested is that there is a unit root in the variable (non-stationary), and alternate hypothesis stating that there is no unit root (stationarity).

Initially all the variables are to be categorised into the pre-, post-automation and the total period, as was done in the study by Freund Larrain and Pagano (1997). The ADF and PP tests will then be performed on the sub-groups. However, to increase precision of testing, the log of the variable will also be taken.

Analysing the results for each period and then cross analysing them against the results for the other periods will determine if the variables are non-stationary. The variables that are found to be integrated of order one, I (1) in all three test groups will be further tested for cointegration and causality.

Johansen cointegration test

Engle and Granger (1987) showed that a linear combination of two or more non-stationary series might be stationary. For this study the Johansen cointegration test will be performed to identify the number of cointegrated relationships (vectors) in the equations. The stationary linear combination is called the cointegrating equation, and may be interpreted as a long-run equilibrium relationship between the variables. In the procedure developed by Johansen and Juselius (1990) the likelihood ratio is compared with the critical value at the given level of significance. This technique will be used as it is relatively more powerful than the two-step procedure proposed by Engle and Granger (Taylor and Sarno, 1997).

Following Johansen and Juselius (1990) the Vector Autoregressive (VAR) system can be written as:

$$\mathbf{Y_t = \xi + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \ldots + \Pi_{k-1} Y_{t-k+1} + \Pi_k Y_{t-k} + \varepsilon_t} \qquad (2)$$

where Y_t is a k x 1 vector of variables, Π are k x k coefficient matrices, ξ is k x 1 vector of constants and ε_t is a vector of disturbance or error terms. The long run static equilibrium corresponding to equation (2) is:

$$\mathbf{\Pi Y = 0} \qquad (3)$$

where the long run coefficients matrix is defined by:

$$\mathbf{1 - \Pi_1 \;\; \Pi_2 - \ldots - \Pi_k = \Pi} \qquad (4)$$

Equity and futures prices cannot be cointegrated unless the time series is non-stationary. The unit root tests discussed in the previous section will uncover the properties of the time series. The Johansen procedure tests the restrictions imposed by cointegration on the unrestricted Vector Auto Regression (VAR) involving the series.

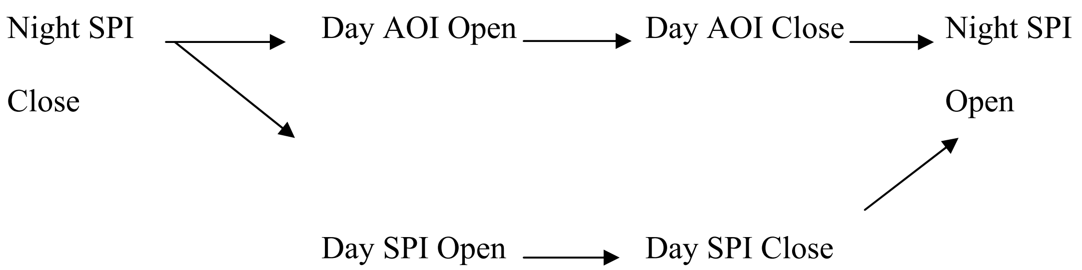
If we cannot reject the hypothesis that the number of cointegrating equations is zero, the series is not cointegrated. To allow for the possibility of changes over time in the cointegrating relationship over the two sub periods, the Johansen (1991) framework can be used. The first sub group is as mentioned earlier the pre-automation, and the second subgroup called post-automation. This sub period approach to sub grouping was also performed in the study by Ackert and Racine (1999).

In this study, Johansen's procedure will be used to verify the existence of cointegration, examine the number of cointegration vectors and the coefficients of the long-run equilibrium relationship. The Granger Causality (Granger, 1969, 1981) test in this study aims to provide and establish the relationship of price discovery from the asset market to the futures market on a daily basis. The implementation of this methodology can determine whether the structural alignment of the SFE systems has had any effect of the price discovery process

Lead-lag relationship (Causality)

Figure 1 shows the information flow through the ASX and SFE.

Figure 1: Information Flow through Time in the Market Prices



The Granger (1969, 1981) causality test will be run on the two sub-periods (pre- and post-automation). This will be done to establish whether any causality of variables is present. This result will then be contrasted against the post-automation results to establish whether the price discovery process has been maintained, increased or decreased the informational flow between markets, to lead one price against another.

4.0 Analysis of results

4.1 Descriptive Statistics

The discussion begins with the presentation of the descriptive statistics as shown in Tables 2 and 3. The objective of this section of study is to provide an insight into the nature of the volume variables through the presentation of their statistical characteristics. These results are presented for the pre-automation period (represented by ‘PRE’ in all the tables) from 2 January 1998 to 3 March 1999. The post-automation period (represented by ‘POST’ in all the tables) covers the period from March 3, 1999 to August 1, 2000. Table 2 reports the volume liquidity variables while Table 3 presents the descriptive statistics of the volume liquidity ratio variables.

Table 2 Descriptive Statistics for the Volume Liquidity Variables

Statistics on Liquidity	PRE ATM SPI	POST ATM SPI	PRE AOI	POST AOI	PRE SPI Futures	POST SPI Futures
Mean	208.46	332.95	211070.20	236418.19	10390.62	10671.72
Standard Error	22.26	35.19	3243.51	3710.86	214.77	195.55
Median	65.0	59.5	206381.0	224115.0	9967.0	9963.5
Standard Deviation	323.38	535.94	54948.61	67411.17	3663.63	3552.38
Sample Variance	104576	287228	3019349809	4544266018	13422165	12619411
Kurtosis	4.73	7.08	2.15	4.10	1.23	2.71
Skewness	2.16	2.50	0.74	1.33	0.80	1.23
Range	1764	2894	449689	555846	25096	23852
Minimum	1	1	31339	67891	807	4332
Maximum	1765	2895	481028	623737	25903	28184

* Descriptive statistics are for the volume variables stated above: share price index (SPI), All Ordinaries Index (AOI), at the money option contracts (ATM).

As shown in Table 2, the post-automation statistics depict greater volume averages (means), along with greater standard deviations, and trading ranges than those of the pre-automation period. Both the skewness and the kurtosis of the post-automaton period are higher when compared with those of the pre-automation period.

Table 3 presents the ratios of the variables included in Table 2. The ratios aim to isolate the relative change of one volume in relation to the other volume, allowing for the comparison of trading activity of each market (futures market and share market). The volume liquidity variables from Table 2 are used in the calculation of the liquidity ratios in Table 3.

In Table 3 the post–automation mean values and standard deviations reveal that ‘at the money’ (ATM) option contract volume ratio (columns 2 through to 5) has increased in proportion to the change in the other volume denominator (the SPI futures and the All Ordinaries Index, AOI). However, the post-automation means and standard deviations infer the opposite about the SPI futures, in that volume ratio has marginally decreased relative to the pre-automaton volume ratio (last 2 columns of Table 3). The ATM ratios have seen an increase in kurtosis and a reduced skewness in the post automation results (columns 2 through to 5). The SPI futures/AOI ratio (columns 5 and 7) has increased in kurtosis, skewness and range after automaton. The next section will endeavour to examine whether the liquidity in the Sydney Futures Exchange has changed.

Table 3 Descriptive statistics for the liquidity ratios

Statistics on Liquidity Ratios	PRE ATM/SPI Futures	POST ATM/SPI Futures	PRE ATM/AOI	POST ATM/AOI	PRE SPI Futures/AOI	POST SPI Futures/AOI
Mean	0.464	0.473	0.348	0.355	0.751	0.747
Standard Error	0.015	0.015	0.011	0.012	0.002	0.001
Median	0.500	0.488	0.375	0.374	0.752	0.746
Standard Deviation	0.203	0.221	0.151	0.168	0.028	0.026
Sample Variance	0.041	0.049	0.023	0.028	0.001	0.001
Kurtosis	-0.932	-1.295	-0.927	-1.300	0.473	2.351
Skewness	-0.263	-0.190	-0.268	-0.164	-0.320	-0.497
Range	0.790	0.774	0.568	0.578	0.179	0.210
Minimum	0.071	0.073	0.055	0.055	0.647	0.606
Maximum	0.861	0.848	0.623	0.633	0.825	0.816

*Natural logarithm of all liquidity ratios were taken to provide statistics. Variable definitions are the same as given in Table 2.

Overall Tables 2 and 3 suggest that the market seems to have been more active in the post-automation period based on trading volumes and volume ratios. This could be due to an increase in the level of trading, related to new information entering the market, such as the information relating to technology stock crash in early 2000.

4.2 ANOVA results

The examination of the pre-automation period and the post-automation period involves the use of 'analysis of variance' (ANOVA) tests. ANOVA is a statistical test to determine the existence of differences among sample means. An ANOVA test assumes that independent random sampling for each of the r sample, with the r sample in the study being normally distributed, with means μ_i that may or may no be equal, but with equal variance σ^2. Thus, the null hypothesis test of an analysis of variance states that the mean of sample one is equal to the mean of sample two. The alternate hypothesis states that the mean of sample one does not equal the mean of sample two. The pre-automation mean will be ANOVA tested to determine if it is equal to the post-automation mean. This analysis will reveal any significant change in the volume variables over the two periods surrounding the automation of the Sydney Futures Exchange.

The ANOVA results are presented in two panels in Table 4. Panel A of Table 4 is the option moneyness portfolios[7]. Panel C of Table 4 presents the ANOVA test results for the liquidity ratios earlier given in Table 3. Under the assumption of the mixture of distribution hypothesis (MDH)[8] Table 4 can be used to examine the change in liquidity relating to the change in market volatility. The MDH approach aims to examine whether the post-automation period mean daily volume has significantly increased relative to the pre-automation mean. The results can then be compared to determine the level of trading after automation to a particular level of market volatility. The following section provides an analysis of the option contract statistics and ANOVA tests on the above lines.

Option contracts

In Table 4 ANOVA test results are presented. The null hypothesis is that the pre-automation variable mean is equal to the post-automation variable mean. The results presented are those that rejected the null hypothesis.

Table 4 (Panel A) reveals that mean values of post-automation option moneyness portfolio are greater than the mean values of post-automation option moneyness, except for pre-automation and post-automation FITM[9] (3 months to expiration portfolios). In general, the results show the option contracts that are ‘at the money’ (ATM) or close to the money (‘in the money’ and ‘out of the money’) have mean values that reject the null hypothesis. Even the option contract with the decreased mean values in the post-automation period the “far in the money’ (FITM with 3 months to expiration) is found to be significant to the 5% level. This may have occurred due to a shift in market sentiment about likely future events in three months. However, the closer to the money contracts (ITM and ATM) with 3 months to expiration also have mean values that have increased significantly. Overall these result show that there has been a liquidity change in the SFE in accordance with research proposition 1, with the evidence showing an increase in volume trading in the post-automation period.

[7] A moneyness portfolio denotes the categorisation of strike prices relative to the spot price, so as to create portfolios reflecting the moneyness at that point in time (Rubinstein, 1994).

[8] A brief discussion on the mixture of distribution hypothesis was given earlier.

[9] Variables definitions are given within Table 4.

Table 4 ANOVA Tests

Panel A: Option Moneyness	Sample Size	Mean	ANOVA: Single Factor (P-value)
Pre ATM (1)	507	86.3432	0.04061**
Post ATM (1)	706	109.5864	
Pre OTM (2)	50	48.2800	0.00140***
Post OTM (2)	70	272.1143	
Pre FITM (3)	108	224.3796	0.03522**
Post FITM (3)	126	125.5794	
Pre ITM (3)	338	122.2781	0.01092**
Post ITM (3)	494	180.9919	
Pre ATM (3)	209	119.6459	0.07833*
Post ATM (3)	402	166.7463	
Pre ATM (1a)	211	208.4597	0.00363***
Post ATM (1a)	232	332.9483	

Panel B: Liquidity of AOI	Sample Size	Mean	ANOVA: Single Factor (P-value)
Pre AOI	287	211070.2021	5.24017E-07***
Post AOI	330	236418.1939	

Panel C: Liquidity Ratios	Sample Size	Mean	ANOVA: Single Factor (P-value)
Pre ATM/AOI	209	0.0011	0.0990*
Post ATM/AOI	231	0.0014	
Pre Futures/AOI	287	0.0508	0.000884***
Post Futures/AOI	330	0.0464	
Pre Log Futures/AOI	287	0.7513	0.0381**
Post Log Futures/AOI	330	0.7468	

Variable Definitions:
ATM = at the money
OTM = out of the money
ITM = in the money
FITM = far in the money
AOI=All Ordinaries Index

(1) denotes contractual expiration of 1 month
(1a) denotes contractual expiration of 1 month (refined data set for the use for ration analysis)
(2) denotes contractual expiration of 2 months
(3) denotes contractual expiration of 3 months

*** Denotes rejection at the 1% significance level
** Denotes rejection at the 5% level
* Denotes rejection at the 10% level

In relation to the All Ordinaries Index (AOI) the null hypothesis is rejected as shown in Table 4 (panel B). The AOI may have had a significant mean value increase as the market had more trading volume generally in the post-automation period (such as the trade activity surrounding the technology crash in April 2000).

Table 4 (Panel C) also presents significant results for the liquidity ratio tests. The ANOVA results are consistent with the earlier findings using descriptive statistics. The null hypothesis is rejected to find a statistically significant increase in the AOI volume ratio means in the post-automation period. The 'at the money' option contract with 1 month to expiration relative to market index (ATM/AOI) also rejects the null hypothesis to find that the post-automation mean value increases. Further consistency with the descriptive statistics is shown with the significant SPI futures to AOI liquidity (log futures /AOI) ratio mean value decreasing in the post-automation period in a statistically significant manner.

Overall the results given in Table 4 seem to imply that option trading appears to have become increasingly accepted, as compared to the rate of application of the other derivatives product (futures contract) examined. The evidence supporting this notion comes from the liquidity ratio ANOVA results (Table 4: Panel C) for the increase in the 'at the money' options result, when contrasted to the decrease in the futures contract (results show an inverse relationship).

Based on the above empirical evidence there is clear support for research proposition 1 since there has been a significant change in liquidity and liquidity ratios. The next section will further examine whether the change in liquidity and liquidity ratios has been due to the electronic trading system or whether the market has been more volatile in the post-automation period resulting in higher volumes traded.

ANOVA ratio results ranked to market volatility

This section attempts to provide better insight to the previous ANOVA tests. The aim is to determine whether the increase in volume is due to automation in the SFE, or due to a more volatile market. This will be completed by examination of the pre-automaton and post-automation liquidity ratio variables in the form of volume groups, under the theoretical assumptions that underlie the mixture of distributions hypothesis (MDH). This will enable a more concise analysis of the liquidity ratios, as the performance of liquidity can be measured at different market volatilities. MDH is used to explain why the relationship of the absolute change in price is positively correlated with trading volume. In simple terms, it takes a proportional amount of volume to move the market price to adequately reflect the new information (Harris, 1982; Tauchen and Pitts, 1983). Therefore, volume size can be used as a proxy to market volatility.

The volume groups have been generated to control for the impact of informational content for the market. The volume groups can be categorised by ranking the volume based on size. Volume groups will have equal sample sizes. The first groups will contain the days of the largest volumes. This is due to a large number of trades for the days were required to establish equilibrium within the market. The following groups will then be nominated in descending volume size to a group. Thus, with volume group 5 containing the smallest volume sample. When assessing the groups for the ratio analysis, the denominator in the ratio will be ranked .The volume groups in the liquidity ratio will be assessed on the volume size of the denominator. Such groups will therefore be representative of the information arrival in the market, and the necessary amount of volume to change the price to reflect the new information. This methodology enables information to be held constant, as a level of market volatility, and thus allowing the examination of the corresponding volume group pre-automation and post-automation mean values to be ANOVA tested.

This will determine the level of liquidity in the market at differing levels of market volatility. Hence it is possible to find out whether there has been a change of liquidity since the introduction of electronic trading at the SFE. The significant results are found in Table 5. Results of ANOVA tests found only four of the five volume groups to reject the null hypothesis (the mean values of the pre-automaton variable equals the mean value of the post-automaton variables).

Statistically significant findings in Table 5 seem to add further weight to the previous ANOVA test results presented in Table 4. The null hypothesis for the mean values being equal to one another have been rejected. As shown in Table 5 the post-automation large volume groups (groups 1 and 2) 'at the money' (ATM) liquidity ratio mean values increase relative to the pre-automation volume means. This result suggests that option contracts in the SFE are more heavily traded on days of high market volatility at the Australian Stock Exchange (ASX). The SPI futures liquidity ratio is significant, as null hypothesis is rejected to reveal that a decrease in the medium to small volume group (groups 3 and 4) mean values for the post-automation period.

Table 5 ANOVA Results for Liquidity Ratio Groups

Volume Group	ANOVA Summary for corresponding Volume Group			
	Group Variable	Group Sample Size	Average	P-value
3	PRE Night Futures/AOI	42	0.00595	0.03380**
	POST Night Futures/AOI	42	0.00461	
1	PRE ATM/Futures	42	0.01110	0.01427***
	POST ATM/Futures	42	0.02696	
2	PRE ATM/Futures	42	0.01614	0.01829***
	POST ATM/Futures	42	0.03715	
2	PRE Futures/AOI	42	0.04979	0.05886*
	POST Futures/AOI	42	0.04266	
3	PRE Futures/AOI	42	0.05291	0.06909*
	POST Futures/AOI	42	0.04726	
4	PRE Futures/AOI	42	0.05426	0.052025*
	POST Futures/AOI	42	0.04849	
2	PRE ATM/AOI	42	0.000652	0.0954*
	POST ATM/AOI	42	0.001297	

*** Denotes rejection at the 1% significance level

** Denotes rejection at the 5% significance level

* Denotes rejection at the 10% significance level

AOI = All Ordinaries Index

ATM =at the money

In summary, based on the results presented in Table 5, it can be tentatively suggested that the option contracts appear to have been embraced by market participants on days of high market volatility, as an apparent substitute for futures trading. This is shown in the significant decrease in the futures volumes in the post-automation period for days with medium to smaller market volatility (groups 3 and 4 in Table 5). Overall, the results seem to show that the market participants have a shifting preference in their choice of derivative products since automation. The option market has seemingly become more liquid on days with high volatility (groups 1 and 2 in Table 5), while the futures trading has become less liquid on days of medium volatility, relative to the reaction of the All Ordinaries Index.

As shown above ANOVA results in Table 5 also support research proposition 1. The results from the ANOVA tests clearly show that there has been a change in the liquidity at the SFE since the commencement of electronic trading. This change in liquidity appears to be independent of the more volatile market, as determined by the volume groups. To give further strength to the acceptance of the research proposition 1, the next section will provide a definitive conclusion about the change in the liquidity by regression analysis. It aims to provide further evidence on the automation process of the SFE, and determine whether the change in liquidity is due to volatile market conditions.

Ratio analysis

The final set of tests on the examination of liquidity at the Sydney Futures Exchange is based on regression analysis. The tests aim to provide additional evidence on the presence of liquidity change after the introduction of electronic trading at the SFE. A series of regressions have been run using the futures to AOI volume (SPI futures/AOI) ratio as the dependent variable (see Table 6). Independent variables used in the regressions are open interest, futures settlement price, 'at the money' option portfolio volume, and the 'at the money' volume portfolio as a ratio of the All Ordinaries Index.

As shown in Table 6 the regression analysis shows dummy variables representing the volumes of the pre-automation and post-automaton periods are statistically significant, in line with the volume groups shown in Table 5. The regression diagnostics given are in Table 6 are satisfactory. The pre–automaton to post-automation dummy (pre post) coefficient is also significant. This indicates a change in the SPI futures volume relative to the change in volume in the spot index (AOI) after the automation of the SFE. The significant results are supported by the market volatility volume groups being related to an increase in the option portfolios. The smaller volume group (group 5) has been found significant and are negatively related to the dependent variable. This seems to demonstrate that there has been a change in futures volume trading. The at the money (ATM) contracts, as a ratio of the All Ordinaries Index (ATM_AOI in Table 6) is a significant variable in determining the dependent variable. In relation to research proposition 1, it has been clearly demonstrated from the use of dummy variables that there has been a change in the liquidity and liquidity ratios since the automaton of the SFE.

The results of the regression analysis support the above findings in the descriptive statistics and ANOVA analysis to support research proposition 1. These results in the above sections lead the study to conclude that since the automation of the Sydney Futures Exchange the liquidity has decreased in the SPI futures market, and increased in the SPI call options market, relative to the derivative product traded. There appears to have been a substitution effect in the futures market for 'at the money' option contracts. This effect has increased in times of high volatility of new information entering the market, as the option liquidity has increased significantly, where the futures liquidity has declined. This can be seen in the overall lower trading volumes in the post-automation period for medium to smaller volatile days of market participants reacting news announcements. Therefore it seems to be the case that the option market has become more liquid since the automaton of the SFE, while the futures is not as liquid as it was before automaton.

4.3 Price Discovery Analysis

Time Series Properties

Before testing for cointegration, the order of integration of the individual time series needs to be determined. Tests for unit roots and determining order of integration involve the use of Dickey-Fuller and Phillip-Perron tests.

The procedure for testing for stationarity properties of the variables was discussed earlier. In each case, the null hypothesis is that the variable under investigation has a unit root (non-stationary on the level) while the alternative hypothesis is that the variable does not have a unit root (stationary on the level).

The results shown in Table 7 are consistent with findings by Ackert and Racine (1999), and Groenewold (1997) that price quotes for the index futures (Day SPI Close) and the index (AOI Close) are integrated of order one. Furthermore Table 7 provides more additional evidence to support Ackert and Racine (1999), and Groenewold (1997) findings in that both the day and night open and close prices for the index futures and index have non-stationary time series property for daily data.

As shown in Table 7 all the variables are integrated of order one. The automation of the SFE does not seem to have characteristically changed the non-stationary property of the daily and night open and close relationship held between the index prices. Similar results were found by Ackert and Racine (1999), and Groenewold (1997). As the time series for the pre-automation and post-automation have confirmed the time series are integrated of order one, the series can now be tested for cointegration.

Table 6 Summary of Regression Analysis on Liquidity

Variable	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**	**SPI Futures/ ADI**
C	0.0372(0.4981)	0.03599(0.5115)	0.0335(0.5411)	0.02457(0.6525)	0.0048(0.9314)	0.0037(0.9462)	0.0014(0.9796)	-0.0077(.8890)	0.0380(0.0000)
Iog(Open Interest)	-.0002(0.9433)	-6.97E-05(0.9817)	-6.97E-05(0.9817)	-6.97E-05(0.9817)	0.0015(0.6336)	0.0016(0.6029)	0.0016(0.6029)	0.001598(0.6029)	-
Iog(Settlement)	0.0011(0.6859)	0.0012(0.6581)	0.0012(0.6581)	0.0012(0.6581)	0.0028(0.2892)	0.0029(0.2743)	0.0029(0.2743)	0.002907(0.2743)	-
ATM_AOI	0.6335(0.0378)**	0.6400(0.0357)**	0.6400(0.0357)**	0.6400(0.0357)**	-	-	-	-	-
Iog(ATM)	-	-	-	-	-0.0004(0.2090)	-0.0003(0.2180)	-0.0003(0.2180)	-0.000346(0.218)	-
Pre_ Post	-0.0049(0.0001)***	-0.0049(0.0002)***	-0.0049(0.0002)***	-0.0049(0.0002)***	-0.0051(0.0001)***	-0.0051(0.0001)***	-0.0051(0.0001)***	-0.00508(0.0001)***	-0.0045(0.0003)***
VOL_1	0.0195(0.0000)***	0.0182(0.0000)***	0.0207(0.0000)***	0.0297(0.0000)***	0.0197(0.0000)***	0.0185(0.0000)***	0.0208(0.0000)***	0.029971(0.0000)***	0.0306(0.0000)***
VOL_2	0.0118(0.0000)***	0.0106(0.0000)***	0.0130(0.0000)***	0.0220(0.0000)***	0.0117(0.0000)***	0.0105(0.0000)***	0.0128(0.0000)***	0.02197(0.0000)***	0.0222(0.0000)***
VOL_3	-	-	0.0024(0.2105)	0.0114(0.0000)	-	-	0.0023(0.2359	0.01144(0.0000	0.0119(0.0000)***
VOL_4	-	-0.0024(0.2105)	-	-0.0089(0.0000)***	-	-0.0023(0.2359)	-	0.009122(.0000)***	0.0095(0.0000)***
VOL_5	-0.0102(0.0000)***	-0.114(0.0000)***	-0.0089(0.0000)***	-	-0.0103(0.0000)***	-0.0114(0.0000)	-0.0091(0.0000)***	-	-
R- squared	0.4415	0.4437	0.4437	0.4437	0.4385	0.4404	0.4404	0.4404	0.4336
ADJ. R- squared	0.4318	0.4326	0.4326	0.4326	0.4287	0.4293	0.4293	0.4292	0.4266
SE of regression	0.0123	0.0123	0.0123	0.0123	0.0124	0.0124	0.0124	0.01236	0.0124
Sumsqared resid	0.0612	0.0609	0.0609	0.0609	0.0615	0.0613	0.0613	0.061298	0.0621
Iog likelihood	1227.786	1228.588	1228.588	1228.588	1223.189	1223.908	1223.908	1223.908	1224.8819
Durbin-Watson Stat	1.6169	1.6149	1.6149	1.6149	1.6159	1.6153	1.6153	1.61525	1.6043
Mean dependent variable	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.0501	0.050096	0.0501
SD dependent variable	0.0163	0.0163	0.0163	0.0163	0.0164	0.0164	0.0164	0.016366	0.0163
Akaike info criterion	-5.9357	-5.9347	-5.9347	-5.9347	-5.9278	-5.9264	-5.9264	-5.92638	-5.9313
Schwarz SC criterion	-5.857	-5.8467	-5.8467	-5.8467	-5.8494	-5.8382	-5.8382	-5.8382	-5.8726
F- stat	45.5127	-40.0769	-40.0769	-40.0762	-44.841	39.4519	39.4519	39.452	-66.9981
Prob (F- stat)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 7 Time Series Properties of the Variables

Variable	Pre-Automation		Post-Automation		Property
	ADF*	PP**	ADF*	PP**	
Night SPI Open	-1.866245	-2.13309	-2.495074	-2.804573	I (1)***
Night SPI Close	-2.021747	-2.346416	-2.518351	-2.82888	I (1)***
Day SPI Open	-1.915622	-2.203659	-2.61018	-2.198428	I (1)***
Day SPI Close	-1.876280	-2.043389	-2.531016	-2.792202	I (1)***
Day AOI Open	-1.71164	-1.809892	-2.552641	-2.817274	I (1***)
Day AOI Close	-1.743018	-1.829806	-2.512903	-2.780272	I (1)***

*Critical values for ADF are ranging from –3.1359 to –3.1368 at 10%m from –3.4260 to -3.4278, at 5%, and –3.9919 to -3.9947

**Critical values for PP are ranging from –3.1359 to –3.1364 at 10%m from –3.4268 to -3.4275, at 5%, and –3.9917 to -3.9930

*** Denotes variable is non-stationary as it is integrated at level one.

Johansen cointegration tests

Johansen's likelihood ratio tests can be applied to determine the value of r, the number of cointegrated relationships between the variables in Table 7.

Table 8 Johansen Cointegration Test log Results for the Pre-automation Period

Post Automation Variables	Ho:	H1:	Eigenvalues	Likelihood Ratio
SPI Night Close, AOI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.133768 0.018052	56.15137** 6.321137
AOI Day Close, SPI Night Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.15986 0.017473	66.55955** 6.116847
SPI Day Open , AOI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.149069 0.017637	62.18897** 6.174793
AOI Day Close, SPI Day Close	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.162063 0.017576	67.50692** 6.153183
AOI Day Close, SPI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.132571 0.01729	55.40282** 6.051996

*(**) denotes rejection at 5%(1%) significant level

Following the procedure developed by Johansen and Juselius (1990) the number of cointegrated relationships (vectors) in the equation (shown in Tables 8 through to 9) is determined by comparing the likelihood ratio to the critical value at the given level of significance. It is shown in Tables 8 and 9 that the null hypothesis of no cointegrating vectors can be rejected at 1% levels of significance for the variables tested in the pre- and post–automating periods.

Table 9 Johansen Cointegration Test log Results for the Post-automation Period

Post Automation Variables	Ho:	H1:	Eigenvalues	Likelihood Ratio
SPI Night Close, AOI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.171061 0.008075	66.54364** 2.756496
AOI Day Close, SPI Night Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.102473 0.010521	40.47313** 3.60673
SPI Day Open , AOI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.177129 0.09194	69.62966** 3.149613
AOI Day Close, SPI Day Close	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.076209 0.007512	29.6022** 2.571375
AOI Day Close, SPI Day Open	$r = 0$ $r \leq 1$	$r > 0$ $r > 1$	0.087967 0.00663	33.56882** 2.261839

*(**) denotes rejection at 5%(1%) significant level

The above results support the cointegration hypothesis incorporated in research propositions 2 and 3. The results seen in Tables 8 and 9 show that all variables are cointegrated. This concludes that the SPI futures contract is still cointegrated with the All Ordinaries Index before and after the introduction of electronic trading at the SFE.

Findings in this study are consistent with findings of other studies (Kempf and Korn, 1998; Ackert and Racine, 1999; and Turkington and Walsh, 1999) that the behaviour of index prices is consistent with the semi-strong form of the efficient market hypothesis. The above results in Tables 8 and 9 provide evidence that the spot and futures prices are in a cointegrated equilibrium relationship. However, no previous empirical evidence has been provided to support the findings in this study for night open and close prices for a cointegrated relationship. Overall, results using cointegration approach provide evidence supportive of semi-strong form of the efficient market hypothesis.

Granger Causality Tests

As discussed earlier, the price discovery relationship is centred around the lead-lag behaviour of the ASX All Ordinaries Index and the SFE SPI futures contracts. The causal relationship was examined using the Granger causality test to detect the direction of information flow as reflected through price change.

Table 10 Granger Causality Test Results

Panel A: Day Traded Series	**Null Hypothesis**	**Pre-Automation F- Stat**	**Post-Automation F- Stat**
SPI Day Open, AOI Open	SPI day open does not Granger Cause AOI open AOI open does not Granger Cause SPI day open	44.6516*** 0.13576	4.30455*** 0.36373
AOI Close, SPI Day Close	AOI close does not Granger Cause SPI day close SPI day close does not Granger Cause index close	1.94637 0.37811	2.48783* 1.58893
Panel B: Night Traded Series	**Null Hypothesis**	**Pre-Automation** F- Stat	**Post-Automation** F- Stat
AOI Close, SPI Night Open	AOI close does not Granger Cause SPI night open SPI night open does not Granger Cause AOI close	1402.57*** 0.72121	0.59129 59.8435***
SPI Night Close, AOI Open	SPI night close does not Granger Cause AOI open AOI open does not Granger Cause SPI night close	33.2951*** 0.82011	5.46812*** 0.38735
AOI Close, SPI Night Close	AOI close does not Granger Cause SPI night close SPI night close does not Granger Cause AOI close	123.388*** 1.09953	22.0058*** 1.99863

*** (*) Denotes significance at the 1% (10%) level

The results for the Granger causality performed on the day-traded indexes are seen in Panel A in Table 10, and the night-traded index (SPI) is shown in Panel B in Table 10. The causal relationships are to be tested on the open and close prices for the SPI futures and the All

Ordinaries Index. As the unit root test results shown in Table 3 show that the variables are integrated of order one, I(1), the first differenced variables are used in causality tests.

It is observed from Panel A in Table 10 that the day traded All Ordinaries open (day AOI open value) value does cause share price index (day open value), while the share price index (day close value) does cause the All Ordinaries Index (day close value). Causality seems to run both ways (bi-directional causality) from / to the All Ordinaries Index (AOI) to / from share price index futures in the day trades.

The night trades of series are shown in Panel B of Table 10. The share price index (SPI) night close causes the All Ordinaries Index day close value in the post-automation period, whereas the All Ordinaries Index (AOI) day close causes the share price index (SPI) night close in the pre-automation period. Thus, causality seems to run both ways (bi-directional causality) from / to the All Ordinaries Index (AOI) to / from night traded share price index futures in the day trades in the night traded period.

Comparing the pre-automation and the post-automation periods, the results suggest that since automation the structural alignment between the night traded futures and the day traded futures seems to have created a synergy from the 24 hour trading of the SPI futures contract. This can be seen in Table 10 (Panel B), with the shift to the SPI night open causing the AOI close in the post period. The results broadly show bi-directional results over the 24 hours period before and after the introduction of electronic trading at the SFE. Thus research proposition 4 is supported in that the lead-lag relationship remains unchanged (still bi-directional) after the commencement of electronic trading at the SFE.

5.0 Conclusion

This study examined whether the Sydney Futures Exchange has benefited from the introduction of electronic trading. Under the first research proposition empricial tests were carried out on the liquidity of the Sydney Futures Exchange with the analysis of the ‘at the money’ (ATM) SPI call options, and SPI futures contracts. This provided an insight to the change of liquidity between the two derivative markets. By classifying the option contracts by date to expiration and the closeness of the strike price to the spot price, the ATM volume was analysed along with the SPI futures against the All Ordinaries Index (AOI). The tests were run by classifying the volumes into size groups, following the assumptions of the mixture of distributions hypotheses so as to provide relative levels of market volatility to compare the liquidity ratios against.

The results show that the 'at the money' SPI options were more liquid in times of high volatility after the SFE became automated. The SPI futures are less liquid in times of medium to low market volatility. This overall result supports the research proposition 1 that the SFE's liquidity has changed with the introduction of an electronic trading. Therefore it can be concluded that the liquidity of the Sydney Futures Exchange seems to have increased the operational efficiency within the SPI call options market while there seems to have been a decline in the operational efficiency of SPI futures market.

The importance of the analysis of liquidity in this study is that it was able to account for times of high volatility, such as the technology crash at the beginning of 2000. This was clearly shown by segmenting the option and futures market responses to the differing levels of market volatilities.

The examination of the price discovery process was incorporated into the last three research propositions. Research propositions 2 and 3 were used to test semi-strong form market efficiency. Under this assumption the trading prices in the Australian Stock Exchange (ASX) and Sydney Futures Exchange (SFE) should have a long-run cointegrating relationship. The results confirm the belief that ASX and the SFE are semi-strong efficient. The existence of cointegration between the two markets before and after the introduction of electronic trading supported the semi-strong market efficiency.

The presence of a bi-directional lead–lag relationship between the SPI futures price and the All Ordinaries Index price before and after the introduction of electronic trading supported the last research proposition.

The automation of the SFE did alter the price discovery process. Firstly it did appear to synergise the night traded market. This is most likely a result from the SFE day and night structural alignment of both instruments being traded on the same system. However, market lead and lags were bi-directional before and after automaton. This suggests that the electronic trading structure does not greatly enhance the price discovery price of the SFE. If it did, this would be observed in the SPI futures leading the AOI.

Therefore, it can be concluded that a change in the liquidity is evident in the SPI futures and SPI call option contracts, but the price discovery process does not appear to have been enhanced by the automaton of the Sydney Futures Exchange in the early stage up until August 2000.

References

Ackert, L. F. and Racine, M. D. (1999). Stochastic Trends and Cointegration in the Market for Equities. *Journal of Economics and Business*, 51(2):133-143.

Anthony, J.H. (1988). The Interrelation of Stock and Option Market Trading Volume Data. *Journal of Finance*, 43(4):949-964.

Ates, A and Wang, G.H.K (2005). Information Transmission in Electronic versus Open-Outcry Trading Systems: An Analysis of U.S.Equity Index Futures Markets. *Journal of Futures Markets,* July 2005, 25(7):679-715.

Australian Stock Exchange, (2000). < www.asx.com.au/B1400.htm > Accessed on 24 April 2000.

Bortoli, L., Gareth, A. and Jarnecic, E (2004). Differences in the Cost of Trade Execution Services on Floor-Based and Electronic Futures Markets. *Journal of Financial Services Research,* August 2004, 26(1):73-87.

Brailsford, T. (1996). The Empirical Relationship between Trading Volume, Returns and Volatility. *Accounting and Finance,* 36(1):89-111.

Brenner, K. and Kroner, K. (1995). Arbitrage, Cointegration, and Testing the Unbiasedness Hypothesis in Financial Markets. *Journal of Financial and Quantitative Analysis,* 30(1): 23-42.

Brooks, C., Garrett, I. and Hinich, M. J. (1999). An Alternative Approach to Investigating Lead-lag Relationships Between Stock Index and Stock Index Futures Markets. *Applied Financial Economics,* 9(6):605-613.

Clark, P.K. (1973). A Subordinated Stochastic Process Model with Finite Variance for Speculative Prices. *Econometrica*, 41(1):135-155.

Copeland, L., Lam, K. and Jones, S-A. (1976). The Index Futures Markets: Is Screen Trading more Efficient?. *Journal of Futures* Markets, April 2004, 24(4):337-357.

Copeland, T.E. (1976). A Model of Asset Trading Under the Assumption of Sequential Informational Arrival. *Journal of Finance*, 31(5):1149-1168.

Cornell, B. (1981). The Relationship Between Volume and Price Variability in Futures Markets. *Journal of Futures markets*, 1(2):303-316.

Dickey, D. A. and Fuller, W. (1979). Distribution of the Estimators for Auto Regression Time Series with a Unit Root. *Journal of the American Statistical Association*, 74(2):427-431.

Domowitz, G. (1993). A Taxonomy of Automated Trade Execution Systems. *Journal of International Money and Finance*, 12(3):607-631.

Engle, R. F. and Granger, C. W. J. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2):251-276.

Epps, T.W. and Epps M.L. (1976). The Stochastic Dependence of Security Price Change and Transaction Volumes: Implications for the Mixture-of-Distributions Hypothesis. *Econometrica*, 44(2):305-321.

Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance*, 25(2):383-417.

Fama, E. F. (1991). Efficient Capital Markets. *Journal of Finance*, 46(5):1575-1617.

Franke, G. and Hess, D. (1995). Anonymous Electronic Trading Versus Floor Trading. *Working Paper*, Series II, no. 285, Universitat Konstanz.

Freund, W. C., Larrain, M. and Pagano, M. S. (1997). Market Efficiency before and after the Introduction of Electronic Trading at the Toronto Stock Exchange. *Review of Financial Economics,* 6 (1):29-56.

Frino, A., McInish, T. and Toner, M. (1998). The Liquidity of Automated Exchanges: New Evidence from the German Bund Futures, *Journal of International Financial Markets, Institutions and Money*, 8(3-4):225-241.

Frino, A.I. and Jarnecic, E. (2000). An Empirical Analysis of the Supply of Liquidity by Locals in Futures Markets: Evidence from the Sydney Futures Exchange. *Pacific Basin Finance Journal*, 8(3-4):443-456.

Sydney Futures Exchange (SFE) (1999). *Full Electronic Trading: A Guide for Customers*. Sydney, Australia.

Granger, C. W. J. (1981). Some Properties of Time Series Data and Their Use in Econometric Model Specification. *Journal of Econometrics*, 16(1):121-130.

Granger, C.W.J. (1969). Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. *Econometrica*, 37(3):424-438.

Groenewold, N. (1997). Share Market Efficiency: Tests using Daily Data for Australia and New Zealand. *Applied Financial Economics*, 7(6):645-657.

Grunbichler, A., Longstaff, F. A. and Shwartz, E. S. (1994). Electronic Screen Trading and the Transmission of Information: An Empirical Examination. *Journal of Financial Intermediation*, 3(2):166-187.

Harris, L. (1982). Transaction Data Tests of the Mixture of Distributions Hypothesis. *Journal of Financial and Quantitative Analysis*, 22(2):127-141.

Hemler, M. L. and Longstaff. F. (1991). General Equilibrium Stock Index Futures Prices: Theory and Empirical Evidence. *Journal of Financial and Quantitative Analysis*, 26(3):287-308.

Hinich, M. (1996). Testing for Dependence in the Input to a Linear Time Series Model. *Journal of Nonparametric Statistics*, 6(3):205-221.

Hurst, H.E. (1951). The Long-term Storage Capacity of Reservoirs. *Transactions of the American Society of Civil Engineers*, 116(3):143-152.

Jarnecic, E. (1999). Trading Volume Relations Between the ASX and ASX Options Market: Implication of Microstructure. *Australian Journal of Management*, 24(1):77-91.

Johansen, S. and Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration- with Application to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, 52(2):169-210.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Guassian Autoregressive Models. *Econometrica*, 59(6):1551-1580.

Johansen, S. (1995). *Likelihood-based Inference in Cointegrated Vectors Autoregressive Models*. MA: Oxford University Press. Oxford, U.K.

Karpoff, J. M. (1987). The Relation Between Price Change and Trading Volume: A Survey. *Journal of Financial and Quantitative Analysis*, 22(1):109-126.

Kempf, A. and Korn, O. (1998). Trading System and Market Integration. *Journal of Financial Intermediation,* 7(3):220-239.

Kofman, P. and Moser, J. (1997). Spread Information Flows and Transparency Across Trading Systems. *Applied Financial Economics*, 7(3):281-294.

MacKinnon, J.G. (1991). Critical Values for Cointegration tests, in Engle, R.F. and Granger, C.W.J/ (eds.), *Modelling Long-run Economic Relationships*. London: Oxford Publishing Company.

Mananyi, A. and Struthers, J. J. (1997). Cocoa Market Efficiency: A Cointegration Approach. *Journal of Economic Studies*, 24(3):141-151.

Manaster, S. and Mann, S.C. (1998). Life in the Pits: Competitive Market Making and Inventory Control. *Review of Financial Studies*, 36(1):51-64.

Martell, T.F. and Wolf, A.S. (1985). Determinants of Trading Volume in Futures Markets. *Working Paper*, Centre of the Study of Futures Markets, Columbia Business School.

Massimb, M. and Phelps, B. (1994). Electronic Trading, Market Structure and Liquidity. *Financial Analysts Journal*, 50(1):39-50.

O'Connor, S.M. (1993). The Development of Financial Derivatives Markets: The Canadian Experience. *Technical Report*, No. 62, Ottawa: Bank of Canada.

O'Hara, M. (1995). *Market Microstructure theory*. Cambridge, Basil Blackwell Publishers.

Perron, P. (1990). Testing for a Unit Root in a Time Series with a Changing Mean. *Journal of Business and Economic Statistics*, 8(1):153-162.

Peters, E. (1992). R/S Analysis Using Logarithmic Returns: A Technical Note. *Financial Analysts Journal*, 48(6):81-82.

Phillips, C.C. and Perron, P. (1988). Testing for a Unit Root in Time Series Regression. *Biometrika*, 8(2):153-162.

Pirrong, C. (1996). Market Liquidity and Depth on Computerized and Open Outcry Trading Systems: A Comparison of DTB and LIFFE Bund Contracts. *Journal of Futures Markets*, 16(5):519-543.

Ragunathan, V. and Peker, A. (1997). Price Variability, Trading Volume and Market Depth: Evidence from the Australian futures market. *Applied Financial Economics*, 7(5):447-454.

Richardson, M. and Smith, T. (1994). A Direct Test of the Mixture of Distributions Hypothesis: Measuring the Daily Flow of Information. *Journal of Financial and Quantitative Analysis*, 29(1):101-116.

Rubinstein, M. (1994). Implied Binomial Trees. *Journal of Finance*, 49 (3):771-818.

Shyy, G. and Lee, J. (1996). Price Transmission and Information Asymmetry in Bund Futures Markets: LIFFE vs. DTB. *Journal of Futures Markets*, 15(1):437-455.

Tauchen, G. and Pitts, M. (1983). The Price Variability-Volume Relationship on Speculative Markets. *Econometrica*, 51(2):485-505.

Taylor, M.P. and Sarno, L. (1997). Capital Flows to Developing Countries: Log and Short-term Determinants. *World Bank Economic Review*, 11(3):183-212.

Tsang, R. (1999). Open Outcry and Electronic Trading in Futures Exchanges. *Bank of Canada Review*, Spring Issue: 21-39.

Turkington, J. and Walsh, D. (1999). Price Discovery and Causality in the Australian Share Price Index Futures Market. *Australian Journal of Management*, 24 (2):97-113.

Appendix 1 Ratio variables

$$Ratio\_A = \frac{Day\_ATM\_Volume}{Day\_Index\_Volume}$$

$$Ratio\_C = \frac{Day\_Futures\_Volume}{Day\_Index\_Volume}$$

$$Ratio\_D = \frac{Night\_Futures\_Volume}{Day\_Index\_Volume}$$

$$Ratio\_E = \frac{Day\_ATM\_Volume}{Day\_Futures\_Volume}$$

Day = Traded during the day trading session

Night = Traded during the night trading session

Futures= Share Price index futures contract

ATM = At the money SPI call option contracts

Index = All Ordinaries Index