The Microstructure of the Irish Stock Market

by

Patricia Chelley-Steeley* and Brian Lucey**

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*Patricia Chelley-Steeley
Accounting, Finance and Law Group
Aston Business School, University of Aston
Aston Triangle, Birmingham
United Kingdom
Tel +44(0) 121 359 3611
Fax +44(0) 121 359 6470
email: pcs2@stir.ac.uk

**Brian Lucey
School of Business Studies
University of Dublin
Trinity College
Dublin 2
Ireland
Blucey@tcd.ie

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Abstract

This is the first paper that studies the microstructure of the Irish Stock Market empirically. The motivation for our work is that on 7th of June 2000 The Irish Stock Exchange adopted the modern pan European auction trading system Xetra. Prior to this the exchange utilised an antiquated floor based system. This was an important event for the market as a rich literature exists to suggest that the trading system exerts a strong influence over the behaviour of security returns. We apply the ICSS algorithm of Inclan and Tiao (1994) to discover whether the change to the trading system caused a shift in unconditional volatility at the time Xetra was introduced. We also apply a GARCH model and test for variance changes in the period after Xetra was introduced. Because the trading mechanism can influence volatility in a number of ways we also estimate the partial adjustment coefficients of the Amihud and Mendelson (1987) model prior and subsequent to the introduction of Xetra. We find no evidence of volatility changes associated with the introduction of Xetra. However we do find evidence of an increase in adjustment speeds after the introduction of Xetra.

1 Introduction

Throughout most of their history there have been close links between the Irish and London Stock Exchanges. This close relationship was formalised in 1973 when the Irish Exchange became part of "The International Stock Exchange of Great Britain and the Republic of Ireland". This alliance allowed Irish registered companies to obtain a listing on the London Stock Exchange and trade alongside UK stocks(all other non UK stocks traded on SEAQ International). By 1995 when the two stock exchanges formally separated a large number of Irish stocks were cross listed on both the London and Dublin exchanges.

Although the London and Dublin exchanges were closely linked the two exchanges had very different trading systems. From 1986 the London Stock Exchange utilised an electronic quote driven system called SEAQ. In contrast, the system in Dublin was floor based and unautomated. However, on June 7th 2000 a major overhaul of the Irish market took place which saw the introduction of an electronic order driven system called Xetra. Motivated by the numerous studies that have suggested that the trading mechanism can influence the behaviour of stock returns (Cohen, Maier Schwartz and Whitcomb (1985), Black (1986), Amihud and Mendelson (1987), Handa and Schwartz (1995) Huang and Stoll (1996) we examine the effects that the introduction of Xetra had on the returns of both Dublin and London cross listed stocks.

In the first instance, we apply the ICSS algorithm of Inclan and Tiao(1995), which tests for a change to the unconditional volatility of a series. We apply this test to the stock returns of those securities cross listed on both the Irish and the London markets. We examine the dates of all volatility changes to establish whether there is any evidence of a widespread change in variance associated with the introduction of Xetra. Since the effects of changing the trading mechanism may be gradual rather than instantaneous we also apply a GARCH model and test for a change in variance in the post Xetra period.

The results of our volatility tests suggest a lack of consistent changes to volatility post-Xetra. Since the Amihud and Mendelson (1987) model suggests that the volatility of a security is influenced by noise and the speed of adjustment, which may have offsetting influences on volatility, we extend our analysis and consider whether Xetra changed the speed observed prices adjust to fundamental values. We find that the introduction of Xetra caused both London and Irish prices to adjust to their fundamental values more quickly providing a higher degree of operational efficiency in both markets.

The remainder of this paper is set out as follows. Section 2 provides a literature review. Section 3 describes the microstructure of the Dublin and London market. Section 4 describes the data and provides some summary statistics. Section 5 describes the ICSS algorithm and the results from using this test. Section 6 presents the GARCH model we estimate along with the estimation results. Section 7 describes the estimation of the partial adjustment model and provides its results. Section 8 provides a summary and conclusion to the paper.

2 Literature Review

Intense competition between European stock exchanges has induced wide ranging changes to the mircrostructure of these markets. Across Europe there have been a wave of innovations that have modified trading mechanisms, increased the diversity of trading systems and encouraged the development of pan European trading platforms (many of these developments are discussed in detail by Pagano (1997)). As a consequence, attention has re-focused on the impact that changes to market structure might have on the behaviour of stock returns, see for example, Gemill (2001), Chelley-Steleey (2004), or Pagano and Schwartz (2003).

Consideration of the impact that the trading mechanism might have on the behaviour of stock returns is not new. Pioneering work by Amihud and Mendelson (1980,1982), demonstrated how the actions of a dealer, may reduce the noise associated with the price setting process. Market makers contribute to lower volatility, by changing inventory in response to temporary imbalances in the order flow. This smooths prices contributing to lower volatility. Black (1986) argued that the trading mechanism contributes to errors in the analysis and interpretation which contributes to noise in stock returns. The effect of the trading mechanism on return volatility is also considered by Bias (1993) who analyses the performance of fragmented and centralised markets, with different levels of transparency. In the centralised market dealers compete with each other to attract the order flow, and observe the quotes and transactions of competitors. In the fragmented market, transactions arise as a result of bilateral negotiations, and market makers cannot observe their competitors' quotes or the intensity of their desires to trade. The model shows that although the bid-ask spread is the same in both types of markets, the volatility of the spread in the centralised market is higher. More recently Handa and Schwartz (1996) have shown that in a limit order trading system, when there is a shortage of orders, there is a rise in return volatility.

One way of comparing two trading mechanisms empirically is to use the approach suggested by Amihud and Mendelson (1987), who studied the volatility of returns from different trading mechanisms. Because the NYSE opens with a call auction but trades as a specialist dealer market thereafter, open to open returns reflect the influence of the opening auction while close to close returns reflect the influence of the specialist dealer market. Comparisons of opening and closing prices led Amihud and Mendelson (1987) and Stoll and Whaley (1990) to conclude that open to open returns are on average 20% more volatile than close to close returns. This research has encouraged the belief that call auctions have been a more noisy trading mechanism than continuous dealer markets, inducing more volatility[1].

This was questioned by French and Roll (1986), who showed that returns generated immediately following a market closure(holiday, weekend or overnight), are characterised by increased levels of volatility. This has encouraged a perception that price discovery at the open, because of the accumulation of overnight information, gives rise to enhanced volatility. Ozenbas, Schwartz and Wood (2002) also find evidence of opening price volatility but do not attribute this to information arrival. Instead they argue that protracted price discovery, which induces higher volatility after the open can be attributed to factors related to market structure.

A number of recent studies have investigated the effect that changing the trading mechanism has had on the volatility of returns. As a result, the problems of disentangling the effect of the open from market structure effects have been circumvented. Gemmill (2001) and Chelley-Steeley (2004) both examine the volatility of the London Stock Exchange in the aftermath of the introduction of a new electronic order driven system (SETS). Both papers find that volatility is considerably enhanced after SETS is introduced. However, when Ronen (1998) examines a change to the opening trading mechanism at the Tel-Aviv Stock Exchange, he finds that return

1 Amihud and Mendelson (19..) Study the Japanese market and find the intraday call auction is associated with the lowest level of volatility of the day suggesting that call auctions may be the most efficient ....

volatility is not influenced by the trading mechanism. This finding is also supported in experimental work by Theissen (2003) who examines the price setting process of auction and dealer markets.

The distinction between noise and value was formally captured in a partial adjustment model by Amihud and Mendelson (1987). This model is shown below:

$$P_t - P_{t-1} = g(V_t - P_{t-1}) + u_t \qquad 1.$$
$$2 > g > 0$$

where, P_t is the logarithm of observed prices and V_t is the logarithm of the fundamental price. The $\{u_t\}$ are a white noise sequence of zero mean pricing errors which are *iid* with a finite variance, which can be denoted as σ^2. The $\{u_t\}$ reflect the influence of noise, which pushes observed prices away from their intrinsic value. As noise increases, σ^2 becomes progressively larger causing observed returns to become more volatile. Thus fragmentation, the size of bid ask spreads, the price cushioning effect of a dealer, and other effects of the trading mechanism could all influence the magnitude of σ^2.

The coefficient g is a partial adjustment parameter that captures the speed with which observed stock prices adjust to their fundamental value. When $0 < g < 1$, the current transaction price gradually adjusts towards the fundamental value of the stock, if g=0, then transaction prices do not adjust to changes in value. When g=1, there is full but noisy, price adjustment. When g>1 observed prices over-react to new information.

In this model intrinsic prices, V_t, follow a random walk with drift as shown below,

$$V_t = V_{t-1} + e_t + m \qquad 2.$$

where, m is the positive drift which reflects the magnitude of the daily expected return. The $\{e_t\}$ are a series of *iid* random variables, independent of u_t, with a zero mean and finite variance, which can be denoted as v^2.

Under these assumptions Amihud and Mendelson show that the variance of observed returns is given by:

$$var(R) = \frac{g}{2-g} v^2 + \frac{2}{2-g} \sigma^2 \qquad 3.$$

where, $\frac{g}{2-g} v^2$ represents the contribution that the variation in the intrinsic price v^2 makes to the observed variance, while $\frac{2}{2-g} \sigma^2$ captures the influence that noise has on the observed variance. Thus the variance of observed returns is positively related to three factors, the variance of intrinsic prices, the amount of noise, and the magnitude of the partial adjustment coefficient. If $0< g <1$ then the influence of the partial adjustment coefficient will dampen down the influence that noise has on the observed variance, because the partial adjustment process has a smoothing influence on observed returns. But, if g is greater than one (so that the market is over-reacting to new information), the price adjustment effect will be positive increasing the variance of observed returns.

This model shows that the change from one trading mechanism to another can influence the volatility of stock returns. If the new trading mechanism reduces errors made by analysts in the interpretation of new information we would expect noise and therefore stock return volatility to fall. However, the effects on volatility of a fall in noise may be offset if the introduction of a new trading mechanism increases the speed of adjustment.

3 The Microstructure of the Irish and London Stock Market

The Irish Stock Exchange was established in 1793 and throughout its history it has had close links with the London Stock Exchange. In 1973 the Irish Exchange was admitted to the "International Stock Exchange of Great Britain and the Republic of Ireland". During the 1990's the two markets gradually separated. The Companies Act of 1990 gave the Irish Exchange the powers of self-regulation and the Stock Exchange Act of 1995 formally separated the two exchanges.

Prior to the introduction of Xetra the Irish Exchange held two floor based trading sessions. These were held 9.30-10.30am and 2.15-3.15pm each weekday. During each of these sessions member firms were required to employ a representative on the floor. Official trading required members to match buy and sell orders prior to execution. Normal trades matched orders against those from other member firms while "put-throughs" matched buy and sell orders from different clients at the same price. Traders were not allowed to act as a market maker and hold inventory on their own account. However, when dealing for a client without a counterparty they could hold up to 2,000 of inventory when no matching trade existed. This ensured that small traders always had immediacy but exposed those wishing to trade large volumes to counterparty risk.

When a deal was struck the price was noted on a chalkboard. Filled orders were communicated back to the member firms by a "blower" telephone system which informed all firms of the details of the deals made. Deals made after the close of an official session could only be executed at the beginning of the next trading session. It was a widely held belief that the matching system and the small number of member firms operating on the Dublin market created an impediment to competition.

In 1986, the London Stock Exchange launched SEAQ, a dealer trading system consisting of competing market makers with dual capacity. For each stock trading on SEAQ, the system provides an electronic display of bid and ask prices quoted by the market makers registered for that equity. The most competitive prices are highlighted in yellow and are known as the yellow strip or touch. Registered market makers are required to provide firm quotes for trades up to Normal Market Size (NMS)[2] during the mandatory quote period. SEAQ market makers are not allowed to display prices on competing display systems that are better than those displayed on SEAQ.

SEAQ is an example of a fragmented market since over half of all trades are the consequence of telephone negotiation between market maker and customer (Board and Sutcliffe (1995, 1997)). Large trades on SEAQ have the right to be reported with a delay reducing the degree of post trade transparency. Since SEAQ market makers buy and sell on their own account the London market provides immediacy even for large trades.

On June 7th 2000 the Irish stock exchange introduced Xetra as its official trading system, heralding a major overhaul to the microstructure of the Dublin market. The modernisation of the Irish exchange was made against a background of heightened competition between London and Dublin which had increasingly seen trades in Irish stocks migrate to London.

2 NMS approximately reflects the size of the median transaction.

Unlike the floor based system Xetra is a fully electronic trading system able to offer continuous trading throughout the day. Trading is separated into three phases, pre-trading, main trading and post trading. Pre-trading takes place between 6.30 and 7.50 am when traders can add, modify or delete orders. During this time the order book is closed and no information from the order book is disseminated to the market. The main trading phase is divided into two types of trading; auctions and continuous trading. Each auction has three parts. The first is a call stage when market participants are able to enter orders and quotes as well as modify or delete existing orders. During this phase the order book is closed, although information on the state of the order book is provided to the market along with indicative auction prices[3]. The call phase is followed by price determination, which identifies the auction price. The auction price is chosen to allow the highest order volume to be executed, at a single market clearing price. If an auction price can not be determined no orders are executed. When this happens, the best bid and ask limits are displayed. If there is a surplus of orders at this price, an order balancing phase takes place. This allows those orders unable to be executed at the auction price to become available to the market. During the order book balancing phase orders are executed at the determined auction price[4]. The opening auction takes place between 7.50 and 8.00am and a closing auction takes place between 4.28 and 4.30pm. Intraday auctions may also take place.

Continuous trading takes place between 8.00am and 4.28pm, when the order book is fully open, displaying limit orders with accumulated volumes, as well as the number of orders on the book

3 If an indicative price can not be displayed then the best bid-ask prices are displayed instead.
4 Orders can not be changed or added at this stage.

at each limit price. Orders are executed in order of price then time priority. Between 4.30pm and 5.15pm a post trading phase takes place where orders may be added, deleted or modified(these will be executed the following day).

To safeguard price continuity a trading interuption occurs if a security price moves outside specified ranges (known as dynamic or static price ranges). If a volatility interuption takes place during a call auction the call phase is extended until the potential execution price lies within the allowed range. If the price continues to remain outside the dynamic and static range a wider price range is imposed and price determination is allowed to take place. During continuous trading, if the executable price lies outside the range allowed continuous trading is interupted by a call auction.

A limit or a market order may specify a range of execution conditions. Execute or eliminate orders must be executed immediately or as fully as possible. Non-executed parts of an order are deleted without entry into the order book. A fill or kill order is an order which must be executed in full or if this is not possible it is deleted without entry into the order book.

To protect the positions of those trading large volumes, iceberg orders may be placed. These allow an order to be partially hidden. Each iceberg has a peak, (the visible part of the order) and an overall volume(the full order to be executed). In continuous trading, as soon as the peak is completely executed, and if a hidden volume still exists, a new peak is entered into the book with a new time stamp. Iceberg orders participate with their overall volumes in call auctions. Unlike other orders icebergs are only valid for one trading day[5]. All trades on Xetra are reported immediately. Because the order book is always highly visible on Xetra pre trade transparency is

5 Minimum peak sizes and minimum overall volumes are specified foe ISE Xetra.

considerably higher on Xetra when compared to the floor based system. The almost instantaneous reporting of all trades ensures that Xetra also provides higher levels of post-trade transparency. These changes in transparency are likely to give rise to more efficient price discovery.

4 Data and Summary Statistics

We examine a group of Irish stocks that were transferred to the Xetra trading mechanism on June 7th 2000. To be included in the sample each stock must trade between June 6th 1998 and June 5th 2003 and be cross listed in London throughout the sample period. In all this provides us with sixteen companies these are listed in Appendix 1. Each stock was traded on the Irish floor based market between June 6th 1998 and June 6th 2000 but was traded on the Xetra auction system between June 7th 2000 and June 6th 2003.

Daily closing prices were obtained from *Datastream*. We focus on closing prices rather than intraday prices for two reasons. Because the Irish market is thinly traded high frequency prices may provide distorted results. Second, prior to the introduction of Xetra the Irish Exchange did not archive intraday information.

Table 1 contains the variance and first order serial correlation of both Irish and London returns for both sub-periods. Table 1 also presents a variance ratio statistic, which is the ratio of the variance of post-Xetra returns divided by the variance of pre-Xetra returns. A variance ratio greater than one would indicate that stock returns are higher after Xetra was introduced. Prior to the introduction of Xetra there is a tendency for returns in the Irish market to be more volatile than in London, a pattern which is slightly less prominent post-Xetra. The variance ratios for Irish returns suggest a tendency for volatility to be higher post-Xetra. The mean variance ratio is

2.344 showing that average stock return volatility increased by 134% (only eight Irish securities have a variance ratio statistically greater than one). For London returns the mean variance ratio statistic is 2.01(eight securities have variance ratios statistically greater than one).

We also apply a Levene test which is a nonparametric test able to detect a change in variance across two samples. The Levene statistic W is calculated as

$$\frac{(N-k)\sum_{i=1}^{k} N_i(\overline{Z}_i - \overline{Z})^2}{(k-1)\sum_{i=1}^{k}\sum_{j=i}^{N}(Z_{ij} - \overline{Z}_i)^2}$$

where, $Z_{ij} = | Y_{ij} - Y^* |$, and Y^* is the median return of subgroup i. W has an F distribution with *k-1* and *N-1* degrees of freedom. The results of the Levene Test, centred around the transition to XETRA, indicate a significant number of changes to the variance. There are ten examples of a variance change to both London and Ireland, six occur in both markets.

The summary statistics suggest a lack of conformity in the results and no clear pattern emerges. This suggests that either the trading mechanism had no influence on the volatility of pre and post Xetra returns or changes in the trading mechanism may have been asymmetric. Examining volatility across two sample periods alone may be problematic as volatility in the second sub-period may change for reasons unrelated to the trading mechanism. To overcome this problem we apply the ICSS algorithm of Inclan and Tiao (1994) and examine whether there is a widespread change to volatility at the time Xetra was introduced.

5 Detecting Variance Shifts

To estimate the number of changes in variance and the point at which each variance shift occurs Inclan and Tiao (1994) suggest a three step algorithm, applied successfully in Aggarwal, Inclan and Leal (1999). In the first instance, using the full data set the maximum absolute value of the D_k series is calculated as.

$$D_k = \frac{C_k}{C_T} - \frac{k}{T} \qquad k = 1 \ldots T \qquad 4.$$

where, C_k and C_T are the mean centred cumulative sum of squares calculated from the start of the series to the k^{th} point in time (In all their are T observations in each sample). If there are no variance changes over the sample period then the series D_k oscillates around zero but drifts up or down from zero when a variance shift occurs. If Max $| D_k | \sqrt{(k/2)}$ is greater than the critical value[6] (1.358 at 95% level of confidence) then a possible variance change point has been found.

Once a possible change point cp_i has been identified after m observations the data should be partitioned into two groups spanning $(t_1 \ldots t_{.m-1}):(t_{m+1} \ldots T)$. The Max$| D_k | \sqrt{(k/2)}$ statistic is then calculated for each of the two new samples. In each of these two samples an additional change

6 n is the number of observations used to calculate D_k. Under the null hypothesis that the variance is homogeneous over the entire series, asymptotically D_k behaves as a Brownian bridge when underlying returns are i.i.d.. Throughout we consider a confidence level of 95% which has a critical value of 1.358 and prior to the estimation of D_k test whether security returns are uncorrelated.

point could potentially be identified. This would require a further sub-division of the data, until all the data has been examined in intervals t_1 to each change point, until T is reached and no further change points can be found.

In the third step all $\hat{N}$ change points should be recorded in order $cp_1, cp_2 .. cp_{\hat{N}}$. Assuming the two extreme values are cp_0 where $t = 0$ and $cp_{\hat{N}+1}$ where $t = T$. Each possible change point should be re-checked by calculating $|D_k| \sqrt{(k/2)}$ for data observations spanning alternate change points $(cp_i : cp_{i+2})$ until the change points $(cp_{\hat{N}-2}):(cp_{\hat{N}})$ are reached. If Max $|D_k| \sqrt{(k/2)}$ no longer reaches the critical value the possible change point should be eliminated. This step should be repeated until the number of change points found in each pass of the data does not change and the change points found are "close"[7] to those of the previous pass.

Asymptotic critical values for the ICSS algorithm have been determined assuming that returns are uncorrelated. Since Table 1 shows evidence of serial correlation, prior to the application of the ICSS algorithm we apply an ARMA(1,1) filter to each of the stock return series.

Table 3 contains all the variance changes for Dublin returns and shows that the unconditional variance of each stock return series is non-stationary. Most stocks have over ten variance changes during the sample period. Those shifts in variance which occur within one month of the introduction of Xetra are highlighted in bold. Only four variance shifts coincide with the introduction of Xetra. Table 4 contains information on the variance of each stationary variance interval and the percentage increase or decrease each interval represents. This table shows that of the variance changes that coincide with the introduction of Xetra two represent an increase in variance and two represent a decrease in variance.

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7 Inclan and Tiao(1994) suggest within two data points.

The dates of the variance shifts are shown in Table 5 for London returns. Four of the variance shifts coincide with the introduction of Xetra these have been highlighted in bold. Table 6 presents the variances of each interval and shows that three of the variance shifts which coincide with the introduction of Xetra are variance decreases and one is a variance increase.

6 Garch Estimation

The variances presented in Table 1 are useful summary statistics but may be biased because they assume homoscedasticity of returns (the heteroscedastic nature of stock returns is discussed by Mandelbrot (1963), Fama (1965) and Bollerslev (1986)). We enhance our comparisons of volatility by using the GARCH family of statistical processes to model the conditional mean and variance of security returns.

In equation (5) returns are modelled as an ARMA(1,1) process which has been shown to be an appropriate specification for conditional mean returns, (see for example Conrad, Kaul and Nimalendran (1991)) with the addition of the market index M_{jt}. This addition allows us to control for changes in volatility caused by market movements which are unrelated to the trading mechanism. For London returns the market control is the FT-All share index and for the Irish market it is the ISEQ Index.

$$R_{ijt} = \alpha_{ij} + \phi_{ij} R_{ij,t-1} - \theta_{ij} \varepsilon_{ij,t-1} + m_{ij} M_{ijt} + \varepsilon_{ijt} \quad j = 1, 2 \quad i = 1, 2, 3, \ldots 16 \qquad 5.$$

where, R_{ijt} are the returns for security i in either the London market or the Irish market in time t.

The ε_{ijt} is the unexpected return or shock and α_i θ_i ϕ_i and m_{ij} are coefficients. The GARCH model we estimate is the one suggested by Glosten, Jagannathan and Runkle (1993), which allows us to isolate the impact that negative stock returns have on volatility. This model is recommended by Engle and Ng (1993) as the parametric model most able to capture the asymmetries which may give rise to a leverage effect(negative relationship between stock price movement and volatility), see for example, Black (1976) and Christie (1982).

$$h_{ijt} = a_{ij} + b_{ij}\varepsilon^2_{ijt-1} + c_i h_{ijt-1} + d_{ij} D_{1ijt-1}\varepsilon^2_{ij,t-1} + \delta_{ij} D_2 \qquad 6.$$

where, ε^2_{ijt-1} the past volatility shock, appears twice; on its own, and with a multiplicative indicator dummy variable. This variable takes the value of unity if the past return was negative and a value of zero otherwise. Thus the coefficient d_{ij} measures whether the sign of the return influences the conditional variance. If the coefficient is positive, it indicates that a negative shock will have a greater impact on future volatility than a positive shock, ie a leverage effect exists. D_2 is a dummy which takes on a value of zero pre-Xetra but takes a value of unity post-Xetra. Thus if δ_{ij} is positive (negative) returns are more(less) volatile post-Xetra.

The results from the estimation of this model are included in Table 7 for Irish returns and Table 8 for London returns. Almost all b_{ij} and c_{ij} coefficients are significant and many of the securities in both Dublin and London are characterised by leverage effects. The value of δ_{ij} is significant and positive for seven Dublin securities and is significant and negative for nine securities. A similar lack of consensus characterises London returns. Seven of the δ_{ij} coefficients are negative and nine are positive. This suggests that the influence of the trading mechanism may have been asymmetric across the different securities. This would be possible if the trading mechanism influenced both the amount of noise present and the partial adjustment process in the model outlined in Section (2)

7 Measuring the speed of adjustment

To examine the volatility changes further we estimate the partial adjustment model of Amihud and Mendelson using a Kalman Filter. This allows us to examine the contribution that changes in adjustment speeds may have had the unconditional volatility. The Kalman Filter is an estimation process commonly used to estimate "state space" models. These class of models consist of two parts: the transition equation, which describes the evolution of a set of state variables, and the measurement equation, which describes how the data actually observed is generated from the state variables. A detailed account of the Kalman filter can be found in Harvey (1989).

We can re-write the partial adjustment model, of equation (1), as follows

$$R_t = gV_t - gP_{t-1} + u_t \qquad 7.$$

where, R_t is the observed stock return on day t, and all other variables are as previously defined.

If we now re-define gV_t as α_t, we can write equation (1) and (2) in state space form to provide the measurement and the transition equation as shown in equation (8) and (9).

$$R_t = \alpha_t + \gamma P_{t-1} + u_t \qquad u_t \sim N(0, \sigma^2) \qquad 8.$$

where, α_t is a time varying unobservable state variable. The u_t reflects the influence that noise has on current returns which has a variance σ^2. Since V_t is a random walk with drift, the transition equation which describes the unobservable state variable α_t through time can be written as

$$\alpha_t = \alpha_{t-1} + d + n_t \qquad n_t \sim N(0, \sigma_n^2) \qquad 9.$$

where α_t is gV_t and is a random walk with drift, d is the positive drift $g\,x\,m$ and n_t is ge_t which is a random variable with zero mean and finite variance. Thus the values of V_t through time can be obtained by taking α_t and dividing by γ, the estimate of the partial adjustment coefficient.

Within the flexible framework used in this study the partial adjustment parameter of each market is able to adjust to changes in the intrinsic process that originate in either the home market or London. This allows us to determine whether the introduction of Xetra influenced the speed of adjustment. The results from the estimation of this model are provided in Table 9. During both sub-samples the adjustment coefficients for both Dublin and London returns are in general lower than unity suggesting that observed prices adjust gradually to changes in the intrinsic value. This would tend to lower volatility in both markets in the pre-Xetra sub-period.

The average partial adjustment coefficient for Irish registered stocks is slightly lower in London compared to Dublin(however, the median partial adjustment coefficient is slightly higher in London). During the first sub-period four securities have significantly lower partial adjustment coefficients than London while three are significantly higher in London. In the second sub-period the magnitude of the partial adjustment coefficients tends to rise in both markets but particularly in London(the mean partial adjustment coefficient of Dublin and London returns was 0.8755 and 0.8675 respectively but rises to 0.9074 and 0.9460 in the second sub-period. It is also noticeable that there is a rise in the number of cases of overreaction. The implications of a rise in the partial adjustment coefficients is that volatility would tend to rise post-Xetra if the variance of noise and the variance of the intrinsic process remained constant.

The partial adjustment coefficients suggest that the introduction of Xetra did influence stock return volatility even though it could not be consistently detected in measures of variance. The explanation for this is that while noise caused by the trading mechanism may have declined with the new system changes to the price discovery process that speed up the transmission of new information to prices would have offset these changes. The result would be an ambiguous impact of stock returns depending which effect dominated.

Summary and Conclusions

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Table 1 Summary Statistics

In this table σ^2 is variance of daily returns in percentage terms. The VR is the variance ratio which measures the variance of post-Xetra returns to pre-Xetra returns. The ρ are the first order autocorrrlations. A subscript of 1 or 2 determines the sample period being considered. Sample 1 is the pre-Xetra sample and sample 2 is the post-Xetra sample. An I subscript indicates an Irish return an L subscript indicates a London return.

	σ^2_{1I}	σ^2_{2I}	VR_I	$\rho_{I,1}$	$\rho_{I,2}$	σ^2_{1L}	σ^2_{2L}	VR_L	$\rho_{L,1}$	$\rho_{L,2}$	$VR_I - VR_L$	
1	0.0620	0.0658	1.0620	-0.0593	-0.1972	0.0539	0.0298	0.5516	0.0026	0.0454	0.5104	-0.2426
2	0.1981	2.1975	11.0903	-0.0896	-0.3898	0.0986	0.1536	1.5574	0.2127	-0.0410	9.5329	-0.3488
3	0.0470	0.2809	5.9746	-0.0960	-0.1081	0.0135	0.1392	10.2944	0.0700	0.1499	-4.3198	-0.2580
4	0.0325	0.0245	0.7539	0.1653	0.0033	0.0312	0.0187	0.5978	0.2957	0.2096	0.1561	-0.2063
5	0.0875	0.1751	2.0004	0.0151	-0.0569	0.2121	0.0941	0.4436	-0.2283	0.1996	1.5568	-0.2565
6	0.0936	0.0602	0.6431	-0.0214	-0.0023	0.0758	0.0449	0.5930	0.0909	0.1570	0.0501	-0.1593
7	0.2455	0.3020	1.2305	-0.0352	-0.2517	0.0871	0.0463	0.5317	0.2410	0.2074	0.6988	-0.4591
8	0.1152	0.1772	1.5379	0.0048	-0.0740	0.0165	0.0593	3.5913	-0.2297	-0.0139	-2.0534	-0.0601
9	0.0356	0.0661	1.8547	0.0821	0.0603	0.1025	0.1029	1.0043	-0.1051	-0.2192	0.8504	0.2795
10	0.0306	0.0184	0.6021	0.3534	0.1941	0.0480	0.0331	0.6902	-0.0397	-0.0775	-0.0881	0.2716
11	0.0355	0.0309	0.8681	0.0924	0.0533	0.0573	0.0600	1.0476	0.0312	-0.1671	-0.1795	0.2204
12	0.0199	0.0319	1.6000	0.0493	0.1729	0.0229	0.0485	2.1136	0.0085	-0.0473	-0.5136	0.2202
13	0.0633	0.0602	0.9507	0.0517	0.1834	0.0447	0.0820	1.8319	0.0981	0.0306	-0.8812	0.1528
14	0.0050	0.0348	6.9244	0.0825	-0.0015	0.0345	0.1384	4.0090	-0.0416	-0.1493	2.9154	0.1478
15	3.2036	0.0512	0.0160	-0.5644	-0.0540	0.0775	0.1166	1.5041	-0.1458	-0.1975	-1.4881	0.1435
16	0.0390	0.0155	0.3961	0.0217	0.0985	0.0118	0.0218	1.8491	-0.0404	-0.2963	-1.4530	0.3948
Mean	0.2696	0.2245	2.3440	0.0033	-0.0231	0.0618	0.0743	2.0132	0.0137	-0.0131	0.3309	-0.0100
Median	0.0545	0.0602	1.1462	0.0184	-0.0019	0.0510	0.0597	1.2759	0.0055	-0.0274	-0.0190	0.0417

Table 2 Results from the Levene Test

The W is the Levene statistic and *p* is its probability value, a * indicates significance at a 5% level. An L subscript indicates London returns and an I indicates Irish returns.

Company	W_I	p	W_L	p
1	5.65	0.02*	0.08	0.78
2	69.44	0.00*	0.29	0.59
3	52.94	0.00*	27.61	0.00*
4	0.27	0.60	0.38	0.54
5	22.92	0.00*	11.47	0.00*
6	0.34	0.56	0	0.97
7	22.38	0.00*	0.77	0.38
8	12.06	0.00*	2.3	0.13
9	0.39	0.53	4.3	0.04*
10	12.45	0.00*	7.29	0.01*
11	2.56	0.11	4.33	0.04*
12	5.08	0.02*	41.97	0.00*
13	2.02	0.16	24.63	0.00*
14	7.71	0.01*	33.34	0.00*
15	51.34	0.00*	5.32	0.02*
16	0.11	0.74	64.17	0.00*

Table 3: Variance Change Points, Irish Returns

In this table we report the dates of all variance change points identified during the sample period when using the ICSS algorithim for Irish returns. Those in bold coincide with the introduction of Xetra. Below the date the Max $|D_k|\sqrt{(k/2)}$ statistic is given. The critical value at a 5% level is 1.358.

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	
1	21/08/98	21/9/98	24/05/99	23/08/99	6/01/00	28/02/00	9/5/00	16/5/00	17/7/00	15/8/00	15/06/01	4/09/01	879	11/6/02	5/9/02	3/2/03
		1.98	1.88	3.09	4.56	2.12	4.10	2.46	1.69	2.64	2.72	4.25		2.70	1.46	
2	25/1/99	14/9/99	20/1/00	26/1/00	**31/5/00**	1/9/00	22/9/00	6/3/01	21/4/01	25/6/00	28/11/01	9/4/02	14/6/02	30/9/02	18/12/02	
	2.96	2.93	2.49	1.99	**2.15**	2.61	2.08	1.51	2.00	2.09	2.39					
	19/3/03															
3	5/08/98	4/9/98	5/4/99	16/8/99	23/5/00	27/9/01	8/10/10	28/5/02	30/8/02	3/10/02	11/10/02					
	2.27	3.61	2.73	3.44	2.75	8.93	4.77	1.88	1.39	2.83	4.71					
4	26/8/98	6/11/98	6/1/99	13/1/00	1/3/00	**6/6/00**	26/9/00	7/8/01	25/9/01	23/1/02	31/01/02	24/6/02	1/11/02			
	3.20	1.93	1.94	4.99	3.48	**2.00**	4/12/00	3.30	2.32	1.72	3.29	3.56	2.51			
5	22/6/98	11/8/98	31/8/98	9/2/99	10/3/00	16/5/00	25/8/00	29/12/00	10/01/01	8/3/01	3/4/01	15/6/01	10/9/01	13/9/01	8/11/01	
	3.67	3.60	4.82	6.93	5.46	4.69	4.03	3.30	2.90	3.46	3.36	1.88	3.99	2.72	1.72	
	30/1/02	12/3/02														
	2.48	2.84														
6	11/1/99	26/4/99	10/12/99	16/3/00	3/4/00	**28/6/00**	22/9/00	1/01/01	3/1/02							
	2.03	1.51	3.82	2.12	2.51	**2.01**	2.26	2.29	3.60							
7	23/6/98	11/9/98	14/9/99	10/1/00	8/3/00	1/6/00	4/7/00	10/11/00	30/11/00	5/9/01	15/3/02	15/7/02	30/8/02	6/11/02		
	2.17	1.81	2.83	4.41	2.89	3.20	2.34	1.61	3.22	2.83	4.41	2.49	2.45	2.70		
	14/11/03	27/2/03	4/4/03													
	3.34	2.61	2.39													
8	26/6/98	11/1/99	26/3/99	4/5/99	7/10/99	27/9/00	23/2/01	27/4/01	23/5/01	6/7/01	1/10/01	1/11/01	3/6/02	13/01/03	16/5/03	
	6.79	6.59	3.92	4.77	3.57	2.32	2.41	2.49	2.67	3.43	4.70	2.15	4.01	3.79	5.48	
9	11/6/98	7/7/98	4/8/98	13/10/98	3/12/98	13/1/99	2/2/99	11/5/99	2/6/99	22/10/99	29/12/00	22/3/01	25/4/01	15/6/01	24/8/01	
	2.53	2.07	1.68	2.27	2.49	3.12	2.36	2.81	5.65	3.28	5.80	1.93	2.16	3.15	3.47	
	25/9/01	25/2/02	30/10/02													
		4.21	3.92													
10	24/8/98	3/11/98	14/4/00	22/9/00	27/11/00	12/12/00	20/3/01	23/3/01	23/5/01	26/9/01	16/01/00	12/6/02	12/12/00			
	2.07	4.26	2.26	2.61	2.09	4.23	3.57	3.49	2.07	1.81	3.81	2.55	4.23			
11	4/3/99	22/3/99	5/5/99	23/6/99	12/7/99	15/9/99	4/1/00	18/4/00	10/1/01	20/3/01	28/3/01	22/5/01	20/8/01	24/9/01	30/10/01	
	9.58	3.39	2.55	2.89	3.90	2.21	3.26	8.20	8.37	2.08	4.19	2.33	2.39	2.31	2.61	
	26/11/01	26/8/03	10/10/02	4/12/02	13/1/03	29/4/03										
	3.75	3.67	2.03	2.26	2.94	1.36										
12	23/6/98	27/7/98	31/8/98	6/1/99	4/2/99	3/9/99	8/10/99	13/4/00	11/5/00	**19/7/00**	31/7/00	15/11/00	8/12/00	23/4/01	25/2/02	

	2.79	2.41	5.43	5.02	3.32	3.60	3.14	4.71	4.08	**5.26**	4.48	4.94		3.23	2.02
	15/7/02	13/11/01													
	4.17	2.83													
13	10/8/98	1/10/98	15/12/98	23/4/99	10/2/00	25/8/00	7/9/00	29/11/00	14/12/00	16/3/01	28/3/01	7/9/01	21/11/01	5/2/02	13/2/02
	2.67	2.67	3.13	2.69	2.76	2.72	1.93	4.13	2.72	3.57	2.95	4.66	5.17	2.52	2.49
	14/8/02	12/12/02													
	3.83	3.58													
14	6/7/98	4/8/98	25/8/98	31/8/98	1/10/98	16/12/98	1/9/99	25/8/00	9/11/01	26/3/02	20/3/02	29/8/02	23/10/02	29/4/03	8/1/01
	1.37	1.74	2.14	2.43	2.38	2.26	3.61	5.19	5.79	4.98	3.47	6.16	4.86		
	20/3/02														
	6.25														
15	24/9/98	19/11/98	2/11/98	29/1/99	29/2/99	14/6/99	22/7/99	27/2/01	1/3/01	5/9/01	23/10/01	2/1/02	26/4/02	20/5/02	9/7/02
	2.56	3.99	4.07	3.72	4.13	2.94	13.45	11.51	7.35	4.93	1.52	2.26	2.68	2.73	3.87
	16/7/02	19/8/03	22/8/02	1/9/02	12/5/03	15/5/03									
	2.97	2.61	2.23	5.99											
16	15/6/98	7/4/99	31/5/99	7/6/99	23/7/99	29/7/99	13/9/99	30/11/99	31/3/00	14/4/00	28/8/01	28/11/00	5/01/01	6/6/01	**11/6/01**
	8.09	1.67	4.02	3.79	3.88	2.03	4.17	3.29	2.95	5.14	2.41		6.13	1.93	**2.95**
	7/9/01	26/10/01	16/4/02	2/10/02	30/4/03										
		3.49	2.66	2.82	2.56										

Table 4 : Standard Deviations of Each Volatility Interval: Irish Returns

This table contains the standard deviation of each volatility interval for Irish returns. Below in italics is the percentage increase or decrease this represents.

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20	c21	c22
1	0.0185	0.0500	0.0273	0.0149	0.0073	0.0263	0.0131	0.1068	0.0293	0.0540	0.0242	0.0139	0.0450	0.0201	0.0275	0.0188	0.0314					
		171	-45	-46	-51	261	-50	715	-73	84	-55	-43	224	-55	37	-32	67					
2	0.0410	0.0670	0.0305	0.0583	0.0353	**0.0551**	0.1080	0.0481	0.1217	0.0538	0.1057	0.1625	0.0923	0.2632	0.1322	0.0825	0.1703					
		63	-54	91	-39	**56**	96	-55	153	-56	97	54	-43	185	-50	-38	106					
3	0.0199	0.0466	0.0173	0.0285	0.0159	0.0242	0.2240	0.0470	0.0200	0.0400	0.3303	0.0529										
		134	-63	64	-44	52	827	-79	-57	100	725	-84										
4	0.1994	0.0466	0.0173	0.0285	0.0159	0.0242	**0.2240**	0.0470	0.0200	0.0408	0.3352	0.0527										
		-77	-63	64	-44	52	**827**	-79	-57	104	721	-84										
5	0.0102	0.0356	0.0178	0.0110	0.0302	0.0095	0.0177	0.0122	0.0267	0.0141	0.0384	0.0089	0.0240	0.0177								
		249	-50	-38	174	-69	86	-31	120	-47	172	-77	170	-26								
6	0.0247	0.0141	0.0206	0.0421	0.0947	0.0368	**0.0210**	0.0410	0.0264	0.0176												
		-43	46	104	125	-61	**-43**	95	-35	-34												
7	0.0953	0.0377	0.0252	0.0544	0.0238	0.0957	0.0399	0.1237	0.0599	0.1220	0.0378	0.0484	0.0932	0.0323	0.0123	0.0532	0.0211	0.0500				
		-60	-33	116	-56	303	-58	210	-52	104	-69	28	93	-65	-62	331	-60					
8	0.0230	0.0028	0.0196	0.1222	0.0325	0.0187	0.0273	0.0488	0.1260	0.0307	0.0060	0.1072	0.0546	0.0200	0.0035	0.0300	0.0300					
		-88	611	523	-73	-43	46	79	158	-76	-80	1674	-49	-63	-82	753	0					
9	0.0318	0.0059	0.0011	0.0244	0.0085	0.0002	0.0283	0.0133	0.0304	0.0053	0.0219	0.0605	0.0091	0.0372	0.0120	0.0395	0.0179	0.0585	0.0158	0.0244	0.0104	
		-82	-82	2159	-65	-97	11593	-53	129	-83	314	176	-85	308	-68	230	-55	227	-73	54	-57	
10	0.0167	0.0317	0.0139	0.0079	0.0146	0.0461	0.0071	0.0265	0.0028	0.0127	0.0189	0.0076	0.0100	0.0127	0.0189	0.0076	0.0100					
		89	-56	-43	86	215	-85	273	-90	362	49	-60	33	26	49	-60	33					
11	0.0000	0.0345	0.0023	0.0111	0.0416	0.0066	0.0155	0.0396	0.0020	0.0222	0.0827	0.0041	0.0119	0.0249	0.0058	0.0410	0.0138	0.0305	0.0109	0.0400	0.0103	0.0023
		******	-93	388	274	-84	134	156	-95	996	273	-95	192	110	-77	605	-66	121	-64	267	-74	-78
12	0.1481	0.0012	0.0292	0.0045	0.0233	0.0090	0.0234	0.0098	0.0350	0.0025	0.0449	0.0066	0.0608	0.0212	0.0150	0.0068	0.0204	0.0113				
		-99	2354	-85	415	-61	161	-58	256	-93	1669	-85	827	-65	-30	-55	200					
13	0.0180	0.0500	0.0165	0.0406	0.0099	0.0356	0.0214	0.0084	0.0256	0.0093	0.0348	0.0122	0.0968	0.0152	0.0269	0.0121	0.0678	0.0160				
		178	-67	146	-76	260	-40	-61	205	-64	274	-65	697	-84	77	-55	459	-76				
14	0.0089	0.0001	0.0159	0.0002	0.0293	0.0093	0.0043	0.0021	0.0065	0.0157	0.0058	0.0232	0.0057	0.0529	0.0174	0.0265						
		-99	12700	-99	13526	-68	-53	-52	213	143	-63	300	-75	827	-67	53						
15	0.1406	0.0128	0.3375	0.0178	0.4552	0.1138	0.2627	0.0125	0.1676	0.0144	0.0475	0.0300	0.0169	0.0403	0.0100	0.0532	0.0103	0.0300	0.0123	0.0005	0.0003	0.0002
		-91	2540	-95	2451	-75	131	-95	1240	-91	230	-37	-44	139	-75	431	-81	191	-59	-96	-51	-17
16	0.1514	0.0113	0.0002	0.0195	0.0001	0.0438	0.0119	0.0001	0.0168	0.0543	0.0084	0.0207	0.0422	0.0051	0.0104	**0.0038**	0.0124	0.0059	0.0100	0.0036	0.0011	
		-93	-98	10039	-99	35422	-73	-99	17184	224	-85	146	104	-88	105	**-64**	230	-53	71	-64	-69	

Table 5: Variance Change Points, London Returns

In this table we report the dates of all variance change points identified during the sample period when using the ICSS algorithim for London returns. Those in bold coincide with the introduction of Xetra. Below the date the Max $| D_k | \sqrt{(k/2)}$ statistic is given. The critical value at a 5% level is 1.358.

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15
1	25/6/98	5/8/98	2/9/98	24/9/98	27/11/98	28/12/98	23/2/99	3/3/99	24/5/99	29/7/99	30/9/99	21/10/99	26/4/00	**19/6/00**	1/1/01
	2.95	2.81	1.51	2.89	3.81	2.59	1.98	4.47	2.98	2.95	3.99	3.39	3.92	**4.27**	3.80
	15/1/01	3/9/01	17/7/02	29/7/02											
	3.36	2.04	2.21	3.68											
2	23/7/98	26/8/98	31/8/98	25/9/98	2/11/98	17/11/98	26/1/99	29/4/99	15/2/00	21/6/01	28/6/01	30/10/01	21/3/02	27/3/02	25/4/02
	1.95	3.02	1.99	1.56	2.86	3.06	2.58	2.65	3.14	4.63	2.55	3.01	6.19	2.67	3.46
	18/6/02	8/7/02	16/10/02	25/3/03	26/5/03										
	3.72	2.51	2.89	2.45	4.22										
3	20/8/98	8/12/98	8/1/99	21/4/98	11/8/99	23/3/00	25/5/00	3/1/01	27/9/01	4/10/01	20/12/01	27/5/02	1/10/92	9/10/02	11/12/02
	3.86	2.52	5.13	4.13	4.11	5.48	5.28	4.87	7.85	3.47	1.83	3.37	5.71	2.30	2.95
	1/2/03	26/02/03	21/4/03												
	3.65	3.30	1.98												
4	23/7/98	1/9/98	7/9/98	5/11/98	20/11/98	8/2/99	12/2/99	8/11/99	13/1/00	17/4/00	12/2/02	2/7/02	1150		
	2.45	2.14	3.01	3.48	4.14	2.93	1.76	1.76	2.92	3.17	1.80	3.46	1.80		
5	25/1/99	8/11/99	7/3/01	11/4/01	13/9/01	30/1/02	11/3/02	5/7/02	12/7/02	10/1/03	21/2/03	13/3/03	22/4/03	23/5/03	28/5/03
	2.84	8.39	8.29	3.40	3.01	4.00	4.77	4.66	2.44	1.40	2.43	2.37	1.74	2.70	1.45
6	19/6/98	22/7/98	29/7/98	24/8/98	2/9/98	30/9/98	7/10/98	4/1/99	20/1/99	2/6/99	21/7/99	13/12/99	4/4/00	25/9/01	
	2.51	2.97	2.40	2.21	1.73	2.60	3.59	3.93	5.04	2.80	3.22	4.97	4.22	5.15	
7	11/6/98	29/7/98	7/9/98	26/1/99	29/1/99	29/4/99	3/6/99	24/6/99	30/699	20/8/99	26/8/99	3/2/00	26/4/00	27/3/01	27/9/01
	3.95	3.05	3.09	5.47	2.69	1.85	2.76	1.57	3.67	3.51	2.20	4.29	5.48	2.51	2.59
	15/1/02	21/2/02	9/4/02	25/4/02	14/5/02	30/4/02	12/2/02	19/12/02	21/5/03						
	2.55	2.11	2.25	1.40	1.42	2.47	2.85	1.98	1.64						
8	16/7/98	20/8/98	31/8/98	17/9/98	24/9/98	14/10/98	22/10/98	5/3/99	6/4/99	13/4/99	13/4/00	833	15/4/02		
	2.65	1.75	1.87	1.38	2.21	2.21	6.66	4.91	2.87	4.68	6.13	6.43	7.70		
9	4/9/98	7/1/99	19/1/99	28/5/99	17/6/99	15/2/00	21/2/00	17/3/00	24/3/00	18/8/00	12/10/00	14/11/00	8/12/00	15/12/00	20/2/01
	3.15	3.56	2.28	4.64	4.97	3.19	1.96	2.22	3.47	1.90	1.76	1.60	2.05	2.84	2.57
	20/2/01	6/3/02	15/8/02	21/8/02	1128										
	4.25	2.52	2.49	2.98	2.57										
10	25/8/98	15/12/98	**4/7/00**	19/9/01	16/1/02	17/6/02	4/10/02	5/12/02							
	2.45	4.29	**1.69**	2.64	3.57	2.22	2.25	1.74							
11	4/9/98	8/7/99	31/5/00	4/9/00	20/3/01	18/4/01	12/7/02	1176							
	2.68	2.20	2.80	2.51	3.17	2.53	3.67	2.21							
12	21/7/98	2/9/98	27/4/99	19/7/99	3/8/99	14/9/99	5/10/99	4/4/00	15/11/00	11/12/00	15/10/01	12/7/02	18/11/02		

	1.84	2.36	1.69	2.73	2.48	2.75	3.23	3.87	2.27	1.98	3.33	3.18	3.75	
13	4/2/99	11/8/99	22/12/99	**26/7/00**	16/3/01	22/3/01	18/4/01	6/8/01	13/8/02	20/12/02				
	3.23	2.68	2.31	**1.87**	4.38	1.92	2.26	1.74	2.78	2.21				
14	5/10/99	12/4/00	17/5/00	31/8/00	9/10/00	20/11/00	12/01/01	14/3/01	18/01/02	22/3/02	1011	1067	1075	1104
	2.98	7.22	5.18	4.60	1.45	1.64	2.34	2.30	6.85	1.50	3.29	3.62	3.32	3.40
	1130	1135	27/1/03	13/2/03										
	2.73	2.86	2.58	3.36										
15	11/1/99	9/3/99	22/11/99	8/12/99	27/2/01	4/2/01	14/6/01	20/6/01	10/9/01	1/1/02	20/3/02	19/6/02	12/7/02	
	5.50	5.97	2.59	1.68	2.97	2.08	1.42	3.37	2.68	3.13	3.20	2.43	3.40	
16	30/6/98	14/7/98	26/8/98	2/10/98	9/6/99	7/9/99	10/9/99	24/11/99	16/2/00	**15/6/00**	14/12/00	23/10/02		
	1.56	2.15	2.50	2.67	1.73	2.12	2.03	2.31	2.07	**3.12**	3.74	1.60		

Table 6 : Standard Deviations of Each Volatility Interval: London Returns

This table contains the standard deviation of each volatility interval for Irish returns. Below in italics is the percentage increase or decrease this represents.

	c0	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20	c21	c22	c23	
1	0.0359	0.0043	0.0288	0.0111	0.0034	0.0569	0.0198	0.0489	0.0064	0.0175	0.0043	0.0522	0.0172	0.0441	**0.0161**	0.0563	0.0147	0.0167	0.0400						
		-88	573	-61	-69	1578	-65	147	-87	175	-75	1112	-67	156	**-63**	250	-74	13	140						
2	0.0232	0.0055	0.0578	0.0164	0.0082	0.0682	0.0185	0.0511	0.0305	0.0209	0.1108	0.0361	0.0183	0.2814	0.0336	0.0004	0.1300	0.0500	0.0200	0.0007	0.0536				
		-76	952	-72	-50	731	-73	176	-40	-32	431	-67	-49	1437	-88	-99	35448	-62	-60	-97	8027				
3	0.0180	0.0054	0.0120	0.0000	0.0146	0.0067	0.0226	0.0068	0.0208	0.2793	0.0521	0.0343	0.0102	0.1501	0.0405	0.0103	0.1054	0.0125	0.0305						
		-70	123	-100	41256	-54	239	-70	206	1241	-81	-34	-70	1365	-73	-75	921	-88	145						
4	0.0048	0.0139	0.0452	0.0113	0.0570	0.0097	0.0474	0.0126	0.0052	0.0238	0.0132	0.0078	0.0105	0.0185											
		188	225	-75	406	-83	392	-73	-59	359	-45	-41	35	77											
5	0.0382	0.0622	0.0179	0.0969	0.0376	0.0184	0.0532	0.0113	0.0806	0.0211	0.0054	0.0206	0.0100	0.0632	0.0202										
		63	-71	442	-61	-51	189	-79	611	-74	-74	280	-51	529	-68										
6	0.0119	0.0027	0.0252	0.0052	0.0252	0.0090	0.0763	0.0128	0.0591	0.0106	0.0226	0.0098	0.0529	0.0267	0.0155										
		-77	828	-79	381	-64	752	-83	362	-82	113	-57	440	-50	-42										
7	0.0161	0.0000	0.0201	0.0087	0.1121	0.0202	0.0020	0.0318	0.0773	0.0098	0.0549	0.0217	0.0607	0.0222	0.0135	0.0065	0.0140	0.0056	0.0144	0.0536	0.0367	0.0146	0.0634	0.0158	0.0366
		-100	129157	-57	1195	-82	-90	1474	143	-87	460	-60	180	-63	-39	-52	115	-60	158	273	-32				
8	0.0000	0.0071	0.0155	0.0035	0.0086	0.0001	0.0395	0.0001	0.0037	0.0330	0.0067	0.0200	0.0446	0.0003											
		19038	120	-77	144	-98	26854	-100	2680	794	-80	198	123	-99											
9	0.0305	0.0139	0.0517	0.0199	0.0966	0.0223	0.1196	0.0284	0.1502	0.0286	0.0463	0.0145	0.0328	0.1377	0.0312	0.0807	0.0279	0.0162	0.0482	0.0105	0.0200				
		-54	271	-61	385	-77	437	-76	428	-81	62	-69	127	320	-77	159	-65	-42	198	-78	91				
10	0.0157	0.0369	0.0184	**0.0153**	0.0238	0.0105	0.0100	0.0301	0.0201																
		135	-50	**-17**	56	-56	-5	199	-33																
11	0.0391	0.0232	0.0178	0.0302	0.0181	0.0461	0.0197	0.0301	0.0201																
		-41	-24	70	-40	155	-57	52	-33																
12	0.0112	0.0220	0.0131	0.0075	**0.0226**	0.0064	0.0295	0.0101	0.0239	0.0532	0.0253	0.0149	0.0201	0.0101											
		96	-40	-43	**204**	-72	358	-66	137	123	-52	-41	35	-50											
13	0.0266	0.0140	0.0234	0.0154	0.0209	0.1469	0.0366	0.0159	0.0267	0.0422	0.0205														
		-47	67	-34	35	605	-75	-57	68	58	-51														
14	0.0122	0.0060	0.0714	0.0062	0.0320	0.0179	0.0097	0.0284	0.0174	0.0714	0.0261	0.0004	0.0301	0.0000	0.0731	0.0005	0.1806	0.1208	0.0365						
		-51	1091	-91	419	-44	-46	194	-39	311	-63	-99	8250	-100	317913	-99	38723	-33	-70						
15	0.0196	0.0700	0.0192	0.0512	0.0224	0.0905	0.0335	0.0930	0.0164	0.4300	0.0086	0.0363	0.0801	0.0201											
		258	-73	167	-56	304	-63	178	-82	2520	-98	322	121	-75											
16	0.0063	0.0160	0.0059	0.0207	0.0110	0.0064	0.0279	0.0067	0.0135	0.0084	0.0212	0.0129	0.0037												
		155	-63	249	-47	-42	337	-76	103	-38	153	-39	-71												

Table 7: Garch Results Irish Returns

Company	α_i	ϕ_i	ϕ_i	m_i	a_i	b_i	c_i	d_i	δ_i
1	0.0088	0.3030	-0.5355	-0.0200	0.0046	0.1192	0.8388	-0.0341	-0.0004
	(0.000)	*(0.003)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*
2	0.1924	0.3357	-0.6350	-0.1476	0.0070	0.0496	0.9021	0.0002	0.0112
	(0.000)	*(0.000)*	*(0.000)*	*(0.110)*	*(0.000)*	*(0.000)*	*(0.010)*	*(0.000)*	*(0.000)*
3	0.0148	0.2637	0.9327	-0.9271	0.0071	0.3834	0.6358	-0.1276	0.0160
	(0.000)	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*
4	0.0030	0.7992	-0.7183	-0.0927	0.0008	0.0650	0.8931	0.0338	0.0001
	(0.000)	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000)*	*(0.000(*	*0.000*	*0.000*
5	0.1811	0.4873	-0.5909	-0.5490	0.0247	2.8242	0.0939	-2.4660	0.0695
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
6	0.0195	-0.3888	0.3421	-0.1992	0.0029	0.0679	0.8974	0.0174	-0.0011
	0.000	*0.070*	*0.130*	*0.000*	*0.000*	*0.000*	*0.000*	*0.130*	*0.000*
7	0.0116	0.5835	-0.8002	-0.0875	0.0917	0.2456	0.5572	-0.1905	0.0100
	0.000	*0.000*	*0.000*	*0.070*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
8	0.5481	0.2439	-0.2546	0.9757	12.5729	-0.0054	-0.1234	0.0523	6.9990
	0.000	*0.000*	*0.000*	*0.560*	*0.000*	*0.020*	*0.000*	*0.840*	*0.000*
9	0.0445	0.7125	-0.6897	-0.1284	0.0336	0.4759	-0.0198	-0.1693	0.0110
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.060*	*0.000*	*0.000*
10	0.0092	0.4588	-0.1704	-0.1055	0.0240	0.1101	-0.1349	0.1390	-0.0050
	0.000	*0.000*	*0.020*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
11	0.0008	0.8488	-0.7753	-0.0495	0.0044	0.0402	0.8013	0.0927	-0.0005
	0.000	*0.000*	*0.000*	*0.060*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
12	0.0133	0.7916	-0.7058	-0.0941	0.0205	-0.0716	0.0549	0.0549	0.0101
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.760*	*0.130*	*0.510*	*0.000*
13	0.0010	0.5154	-0.3702	-0.1683	0.0271	0.1743	0.3383	0.3734	-0.0086
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
14	0.5760	0.9042	-0.8500	-0.3226	0.4912	0.0503	-0.0518	-0.0054	3.1920
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.010*	*0.590*	*0.000*	*0.000*
15	0.1795	-0.5313	0.3034	-0.0031	0.8408	0.1953	0.2564	0.1451	-0.8004

	0.000	*0.000*	*0.080*	*0.960*	*0.000*	*0.290*	*0.000*	*0.600*	*0.000*
16	-0.0327	0.4907	-0.2850	-0.0177	0.0050	0.1716	0.6262	0.1563	-0.0025
	0.000	*0.010*	*0.170*	*0.510*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Table 8 : Garch Results London Returns

Company	α_i	ϕ_i	ϕ_i	m_i	a_i	b_i	c_i	d_i	δ_i
1	-0.4063	-0.0007	0.0030	0.0030	5.0597	0.0503	0.0578	-0.0678	-2.3790
	0.000	*0.000*	*0.000*	*0.890*	*0.000*	*0.000*	*0.780*	*0.000*	*0.000*
2	0.0727	0.5984	-0.4554	-0.0418	0.0130	0.2091	0.7271	-0.1156	0.0141
	0.000	*0.000*	*0.000*	*0.480*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
3	0.0426	0.4783	-0.3714	-0.0493	0.0047	0.0928	0.5616	0.0015	0.0343
	0.000	*0.000*	*0.050*	*0.110*	*0.000*	*0.000*	*0.000*	*0.370*	*0.000*
4	-0.0255	0.3898	-0.1627	-0.0600	0.0217	0.1109	0.0887	0.0613	-0.0073
	0.000	*0.000*	*0.260*	*0.060*	*0.000*	*0.020*	*0.349*	*0.400*	*0.000*
5	0.1106	0.4852	-0.6300	-0.2149	0.0600	1.5315	0.2582	-0.9771	-0.0350
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.110*	*0.000*
6	0.0445	0.4536	-0.2238	-0.0494	0.0000	0.0905	0.7313	0.1314	-0.0060
	0.000	*0.000*	*0.070*	*0.220*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
7	0.0575	0.5106	-0.3677	0.1112	0.0282	0.8666	0.1972	-0.7350	-0.0045
	0.000	*0.000*	*0.020*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
8	0.1198	-0.1079	0.1088	-0.0584	0.0120	-0.0011	-0.0169	0.2837	0.0405
	0.000	*0.900*	*0.090*	*0.080*	*0.000*	*0.800*	*0.000*	*0.000*	*0.000*
9	0.1828	-0.4527	-0.0507	-0.2686	0.0046	0.2268	0.8295	-0.1309	-0.0014
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
10	0.0420	0.1163	-0.1579	-0.1455	0.0017	0.0536	0.8860	0.0577	-0.0006
	0.000	*0.740*	*0.630*	*0.000*	*0.000*	*0.010*	*0.000*	*0.020*	*0.000*
11	-0.0007	0.0195	-0.0819	-0.1336	0.0400	0.1629	0.0426	0.1375	0.0022
	0.000	*0.920*	*0.680*	*0.000*	*0.000*	*0.000*	*0.400*	*0.000*	*0.000*
12	0.0202	0.8425	-0.8151	-0.1319	0.0049	0.1016	0.5877	0.2374	0.0049
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
13	0.0168	0.7417	-0.7405	-0.1899	0.0223	0.1152	0.3347	0.2149	0.0090
	0.000	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
14	0.0534	0.3692	-0.5257	-0.0998	0.0015	0.0789	0.8914	0.0017	0.0034
	0.000	*0.110*	*0.010*	*0.010*	*0.000*	*0.000*	*0.000*	*0.920*	*0.000*
15	0.0562	0.4107	-0.6367	-0.0971	0.0200	0.1159	0.6305	0.0182	0.0049
	0.000	*0.000*	*0.000*	*0.050*	*0.000*	*0.000*	*0.000*	*0.630*	*0.000*
16	-0.0394	0.1357	-0.3488	-0.0893	0.0048	0.1827	0.5257	-0.0570	0.0010

	0.000	*0.190*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.350*	*0.000*

Table 9 : Estimated Partial Adjustment Coefficients

In this table the γ is the estimated partial adjustment coefficient. The γ(t) is the t statistic of γ. * indicates whether the gamma coefficients are significantly different from one at a 5% level. The I is for an Irish coefficient and the L is for London. A 1 indicates the sample period preceeds the introduction of Xetra while a 2 indicates the sample period after Xetra was introduced. The + indicates that the coefficients using Irish and London returns are significantly different from each other.

	γI^1	$\gamma I(t)^1$	γL^1	$\gamma L(t)^1$	$\gamma I-\gamma L^1$	γI^2	$\gamma I(t)^2$	γL^2	$\gamma(t)^2$	$\gamma I-\gamma L^2$	$\gamma I-\gamma I^1$	$\gamma L-\gamma L^2$
1	0.9857	11.96	1.039	12.3081	-0.0533	1.18476*	12.47	1.0964*	12.62	0.0884+	-0.1991+	-0.0574
2	0.7081*	12.13	0.7086*	12.56	-0.0005	1.0746	12.86	1.3485*	13.97	-0.2739+	-0.3665+	-0.6399+
3	0.8509*	19.16	0.7253*	5.16	0.1256+	1.3484*	10.62	1.2110*	10.08	0.1374+	-0.4973+	-0.4857+
4	0.6183*	15.39	0.6207*	11.11	-0.0024	0.6528*	18.62	0.8077*	17.57	-0.1549+	-0.0345	-0.1871+
5	1.2481*	15.03	1.3582*	14.99	-0.1101+	0.9059*	12.52	0.7447*	15.76	0.1612+	0.3422+	0.6135+
6	1.3063*	8.47	0.8963*	7.09	0.4100+	0.6921*	5.28	0.7402*	14.76	-0.0481	0.6142+	0.1561+
7	0.7479*	7.39	0.7489*	7.99	-0.0010	0.7563*	14.77	0.9273*	7.16	-0.1710+	-0.0084	-0.1784+
8	0.8756*	12.47	0.7579*	8.47	0.1177+	0.9272	7.3	0.6161*	5.87	0.3111+	-0.0516	0.1418+
9	0.8937*	10.46	1.0275	9.58	-0.1338+	0.9862	5.66	1.0946*	5.63	-0.1084	-0.0925+	-0.0671
10	0.8757*	9.32	0.6358*	14.46	0.2399+	0.8156*	11.12	0.7090*	21.46	0.1066	0.0601	-0.0732
11	0.6367*	6.53	0.6558*	7.37	-0.0191	0.8009*	8.62	0.8017*	8.76	-0.0008	-0.1642+	-0.1459+
12	0.9361	18.07	0.8845*	8.32	0.0516	0.8388*	12.15	0.9904	12.85	-0.1516+	0.0973+	-0.1059+
13	0.5732*	6.28	0.8882*	9.27	-0.3150+	0.9168*	7.37	0.9164*	7.93	0.0004	-0.3436+	-0.0282
14	0.8882*	6.38	0.8943*	8.47	-0.0061	0.7867*	8.37	0.9937	7.84	-0.2070+	0.1015+	-0.0994+
15	0.9867	5.83	1.0183	6.26	-0.0316	1.0473*	8.375	1.1538*	8.95	-0.1065	-0.0606+	-0.1355+
16	0.8765*	7.37	1.0208	7.026	-0.1443+	0.7839*	9.27	0.9849	10.31	-0.2010+	0.0926+	0.0359
Mean	0.8755		0.8675		0.0080	0.9074		0.9460		-0.0386	-0.0319	-0.0785
Median	0.8761		0.8864		-0.0043	0.8724		0.9561		-0.0773	-0.0431	-0.0863

Appendix 1: Sample Companies

	Company
1	Abbey
2	Arcon
3	Barlo
4	DCC
5	Dragon Oil
6	Fyffes
7	Kenmare
8	Norish
9	Glanbia
10	Greencor
11	Heiton
12	Irish Co
13	Kingspan
14	Qualceram Shires
15	Unidare
16	United Drug