

# Financial Market Microstructure of EU Emissions Futures

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To my late father, Folorunsho Nathaniel Phillips-Ibikunle.

## Papers Adapted from Thesis

- 2011 **Ibikunle, G.**, Gregoriou, A., Pandit, N. (2011) Price Discovery and Trading After Hours: New Evidence from the World's Largest Carbon Exchange. *International Journal of the Economics of Business* forthcoming.
- 2011 Daskalakis, G., **Ibikunle, G.**, Diaz-Rainey, I. (2011) The CO<sub>2</sub> Trading Market in Europe: A Financial Perspective. In: Financial Aspects in Energy. Springer: Verlag Berlin Heidelberg ISBN 978-3642197086. *Peer-reviewed.*
- 2011 **Ibikunle G.** (2011) *Carbon Futures Liquidity Effects: Evidence from the European Energy Exchange (EEX)*. Conference Paper and Presentation at the 7<sup>th</sup> Scottish Doctoral Management Conference, 26<sup>th</sup>-27<sup>th</sup> May, 2011, University of St. Andrews. *Peer reviewed.*  
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- 2011 **Ibikunle, G.**, Gregoriou, A. (2011) *European Union Emissions Trading Scheme Futures Liquidity Effects: Evidence from the European Energy Exchange (EEX)*. Conference Paper and Presentation at the 8<sup>th</sup> International Conference on Advances in Applied Financial Economics, 30<sup>th</sup> June-2<sup>nd</sup> July 2011, Samos Island, Greece. *Peer reviewed.*

## **Abstract**

The EU Emissions Trading Scheme (EU-ETS) is the main climate change policy instrument of the EU and has a market value of more than €100 billion; it plays an important role in the reduction of global carbon emissions. Liquidity and price discovery are the two main functions of financial markets; if the EU-ETS platforms have been successful they must show evidence of performing these functions. This thesis is motivated by the need to report on this evidence. Specifically, liquidity effects, price discovery and price impact of block trades are investigated using recent data spanning 2008-2011. Spread decomposition with multivariate and univariate regression approaches are used. Analysis of after hours trading on magnitude and timing of price discovery suggests that the after-hours period reveals more information per unit time than the regular trading hours. Low volume trading in low liquidity instruments generates disproportionately high levels of price discovery, the price reflected is however largely inefficient. Since price discovery is associated with trading volumes, the after-hours period, which holds higher trading volume per minute reflects higher price efficiency than the regular trading hours. This level of price efficiency for relatively liquid carbon futures is similar to equity classes as reported by Barclay and Hendershott (2003). Analysis of determinants of price impact of block trades suggests that block trading in the EU-ETS generally induces low price impact. Results indicate that the trend of block trades impact in the EU-ETS is contrary to most of the existing body of evidence from equity platforms. For example, low liquidity and volatility are associated with smaller price impact and also, larger levels of price impact are more likely to occur during the middle of the trading day than during the first or the final hours. The results in this thesis thus contribute to the understanding of some of the key differences in microstructure properties of emission permits trading platforms to other major asset classes. Also, by providing evidence of a maturing market, this thesis implies that a mandatory emissions trading scheme can contribute to the achievement of emissions reduction targets. This is significant for development of global climate change policy and strategic carbon investment.

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The usual disclaimer applies.

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## Introduction

This thesis situates at the intersection of two important finance research persuasions namely; financial markets microstructure and environmental finance. Specifically, three main financial markets microstructure issues (liquidity, price discovery and block trade price impact) are investigated using data from two major EU-ETS trading platforms. These platforms and several others in Europe constitute the largest regional market for emission permits (see Daskalakis et al., 2011 for detailed discussions; chapter 1 also provides a descriptive analysis of the market). I conduct a microstructure analysis of this market between 2008 and 2011.

According to O'Hara (2003), markets have two major functions: Liquidity and price discovery. These two, although frequently overlooked by symmetric information-based asset pricing models, are vital to asset pricing. Market frictions and transaction costs in real world situations underscore the inadequacies of major asset pricing models. Market microstructure literature considers friction in financial markets and the contribution these two important transaction costs elements (liquidity and price discovery). Liquidity and price discovery are associated but are also categorically different, especially in how they inform asset price formation. In this thesis, I hold the view that a market is only informationally efficient to the extent to which its instruments reflect all available information. This includes publicly available information and private information already used in trading i.e. if one limits the argument to the price adjustment process once a foundation price exists. If the instruments reflect all available information; such market can be considered informationally efficient (Fama, 1970). This means prices should only move based on innovation in beliefs (developed based on new information), and if prices were to move without supporting information arriving at the market, the market can be considered relatively less efficient. In microstructure literature, large trades are usually viewed as being privately held information conveying; hence it is not unusual for large trades (with no underlying privately held information) to move prices. This potentially complicates the price discovery process. Price impact of large/block trades on financial markets therefore remains as important an area of market microstructure research within the context of price discovery. Price impact of trades is indeed associated with the state of liquidity in the market (Frino et al., 2007).

Liquidity plays an important role in financial instruments' pricing, O'Hara (2003) makes an interesting analogy: Consider a market with only sellers and no buyers on a particular day of the week; unless the sellers are willing to wait for the arrival of the buyers who are expected to arrive on a later day during the week, there will be no trades, hence no liquidity. Now, imagine that that an agent decides to buy off the instruments from the sellers on their day of arrival and keeps the instruments until the buyers arrive on a later day, then we have trades and liquidity. Liquidity is thus simply the process that connects a buyer to a seller. A spread between the selling and buying price naturally develops as a result of the service provided by the agent or middleman. The liquidity of this hypothetical market, based on the spread earned by the agent is a transaction cost that ultimately affects asset pricing (see for example Grossman and Miller, 1988; Amihud, 2002). Information, liquidity and price discovery are therefore key issues in financial markets, including environmental markets such as the EU-ETS, which is used for trading carbon emission permits. The smooth functioning of the EU-ETS can therefore not be evidenced without considering its performance based on the major market functions of liquidity, price discovery and related microstructure functions. This implies that the efficiency of the market relies on its liquidity and relatively seamless price discovery. These issues can therefore be interrelated in a well functioning market, although not necessarily. Evidence suggesting relatedness of these issues can be found in microstructure literature contributions (see for example Hendershott et al., 2011). As this thesis aims to fill the knowledge gap about these issues in the EU-ETS; in the next paragraphs, I review the microstructure literature for financial markets price discovery, price impact of block trades and liquidity by linking them together from the transaction costs perspective. I will also attempt to link market efficiency to liquidity based on current literature since the connection impact transaction costs, and then in the process also develop links from these strands of market microstructure to the growing literature on the EU-ETS. I will end this introductory section by providing a brief introduction of the empirical contributions contained in my thesis.

The explanation of liquidity given in the foregoing paragraph creates the impression of illiquidity as the premium paid by a buyer of an asset in a buyer initiated trade or price concession by a seller in a seller-initiated trade. Thus, the larger the spread between the bid and offer prices the larger the cost of trade. The spread is a necessity

reflecting the costs borne by the traders and the economic gain for the middleman. Therefore, in quote-driven markets, the market maker quotes provide the basis for measuring transactional costs. The costs however, are not entirely due to the need for immediacy (processing order costs), they result as a result of inventory and adverse selection/information asymmetry as well (see Glosten and Milgrom, 1985). When considering regular sized trades, the spread is usually the only microstructure impact on prices, this explains why Brennan and Subrahmanyam (1996) measure illiquidity by price impact. Their measure is based on Kyle's (1985) model and estimated analogously to Hasbrouck (1991a) and Foster and Viswanathan (1993). They initially employ the Lee and Ready (1991) algorithm in classifying trades into signed trades and then simply estimate the slope coefficient of tick-by-tick price adjustments on signed order flow (size). Their analysis is valid based on several earlier theoretical works (see for example Kyle, 1985; Easley and O'Hara, 1987) and at least an empirical study (see Glosten and Harris, 1988) suggesting that the liquidity effects of transaction costs (especially asymmetric information) are captured by trade impacts. Liquidity effects thus play a role in the price discovery process. However, block trades can potentially cause price shocks larger than the spread components would have (see Kraus and Stoll, 1972; Chiyachantana et al., 2004 among others), hence, Brennan and Subrahmanyam (1996) control for earlier information based on order size and price changes. Movement in price by liquidity motivated block trades may be due to privately held information contained in the trades or misinterpretation of trading intentions at execution (which is usually the case when liquidity induced block trades are executed).

Kraus and Stoll's (1972) contribution is among the earliest studies to establish that block trades do induce price impact. They present main arguments as the reasons for this: 1) Short-run liquidity effects occurring as a result of price compromise suffered because counterparties are not readily available; 2) Price compromise when instruments are not perfect substitutes for each other leading to inefficient trading and hence price impact. Also, the idea that price concessions are granted in order to execute market order underscores desperation to make a trade happen. This in itself conveys information to markets about the potential value of the order to the counterparties; the order thus becomes information-laden leading to price impact. Holthausen et al. (1990) find evidence of premium payment or price concession for execution of

buyer initiated block trades. They argue that buyers in a block trade pay premium; the premium is incorporated permanently in the price consequently, while no evidence of premium payment is found for block sales. Kraus and Stoll (1972) further hold that price impact is higher for block purchases than sales because concession or an implicit commission paid are usually higher for purchases than sales. This suggests that there is indeed premium paid on block sales. A major contribution from Kraus and Stoll's (1972) pioneering work is that they establish a relationship between block trades and price impact (see also Chan and Lakonishok, 1993).

Since liquidity retains the tag of being a transaction cost for traders, when large enough, it should negatively impact asset returns and value (O'Hara, 2003). Suppose the transaction costs attributable to liquidity were reduced perhaps through establishment of a transparent trading mechanism. A mechanism where the true value of assets are reflected hence the market maker need not account for adverse selection costs, then we can safely assume an efficient price discovery process. Studies have reported price impacts on account of switches in platform trading mechanisms (see for example Amihud et al., 1997). This does not necessarily relate price discovery and transaction cost components of the bid-ask spread although in this thesis I present evidence that low adverse selection costs are associated with higher price efficiency for liquid instruments. When the instrument is relatively illiquid, the relationship is not sustained (see chapter 2). This is an important knowledge gap that this thesis fills with evidence provided in chapter 2.

Price discovery entails the absorption of information into asset prices and is always affected by the identity of traders (i.e. whether they are informed or uninformed). If a trader is uninformed, they run the risk of trading with informed traders thus making information a risk issue as far as price discovery is concerned. Uninformed traders must then seek compensation for trading under asymmetric information conditions. The riskiness of their assets cannot just simply be diversified away, since they remain uninformed. Holding more instruments simply add on more potential losses, here the CAPM world does not exist since the conditions are asymmetric (O'Hara, 2003). The presence of informed traders in the market is linked with asymmetric information costs and widening spreads; and widening spreads indicate deteriorating liquidity or rising illiquidity (see for example Hasbrouck, 1991a; Hasbrouck, 1991b). Price

discovery and liquidity are therefore, based on this view, at the minimum weakly related. The innovation of liquidity and price discovery also suggests that degree of market efficiency is predicated on these two major functions of financial markets. The next three paragraphs explore this connection.

As market participants require time to incorporate new information into their trading strategies, a market deemed efficient over a daily horizon does not necessarily translate into a market that is efficient at every point during the day (see for example Epps, 1979; Hillmer and Yu, 1979; Patell and Wolfson, 1984; Chordia et al., 2008). Confirmation of this notion is available in the contributions of Cushing and Madhavan (2000) and Chordia et al. (2005) showing that short-run returns can be predicted from order flows. According to Chordia et al. (2008), this predictability diminishes with improving market liquidity and across different tick size regimes on the NYSE. Chung and Hrazdil (2010) also confirm the diminishing predictability proposition in a large sample analysis of NASDAQ stocks. These two studies thus provide evidence of strong relations between liquidity and market efficiency through the impact of liquidity on the predictability of returns from order flows.

Previous studies have taken a different path in linking liquidity and market efficiency. They examine the connection between liquidity and returns through the demand for premia when transacting in illiquid instruments, they provide varying insights: Pástor and Stambaugh (2003) report the cross-sectional relationship between stock returns and liquidity risks. Their results are in line with findings from Datar et al. (1998) and Acharya and Pederson (2005). Similarly, Amihud (2002) document evidence supporting the hypothesis that expected market liquidity provides an indication of stock excess return in the time series, implying that the excess return to some extent typifies an illiquidity premium. Chang et al. (2010) also find a consistent narration on the Tokyo Stock Exchange.

Chordia et al. (2008) make an insightful argument for the relatedness of market efficiency, price discovery and market liquidity. Consider market makers in a hypothetical market struggling to sustain liquidity supply. This may be as a result of financial difficulties or over-exposure to untenable positions. In any case, when such a scenario exists, pricing strain caused by arriving order flows potentially forces brief



deviation of prices from their underlying worth (hence inefficiency; see Fama, 1970). Thus order flow can give indication of instrument returns, at least over short intervals (see also Stoll, 1978; Chordia and Subrahmanyam, 2004). Experienced and vigilant market participants (perhaps trading with algorithms) are likely to notice this level of deviation from random walk benchmarks. They are likely to tender market orders with the aim of profiting from the arbitrage. The choice of market orders is informed by the need to quickly profit before the arbitrage opportunity disappears, as this would likely be fleeting. The submitted orders from the arbitrageurs, assuming they are made in ample volumes and on time, are the ones that would lead to relieving the pressure on the market makers inventories. This then potentially spurs the correction of the asset prices. According to Chordia et al. (2005), the correction in asset prices decreases return predictability. Since arbitrage traders are more likely to tender these orders when the spreads are narrow (see for example Peterson and Sirri, 2002; Brennan and Subrahmanyam, 1998 for the influence of liquidity on trading tactics), one would expect reduced return predictability when the market is fairly liquid than otherwise. The interrelatedness of liquidity, price discovery, market efficiency and trade impact is therefore evidenced.

Preceding paragraphs discuss contributions based on equity and more traditional financial market platforms since they have been extensively investigated for the microstructure issues under focus. Transaction costs related contributions on exchange-traded permits using high frequency field data have been scarce however, especially for the European carbon futures markets. A lot of general contributions to the transaction cost literature in environmental finance and economics have been to upstream issues such as initial allocation of emission permits and market conception. Convery (2009) provides a broad overview of a number of those studies (see also Burtraw et al., 2011). The literature body in the carbon trading-related finance is growing although very few are focused on market microstructure. A number of studies have been aimed at understanding general financial market characteristics of the EU-ETS. A significant proportion of these studies have been for the previous phase of the EU-ETS, the Phase I. The following paragraphs examine some of the related studies.

On liquidity and price discovery in the EU-ETS, Benz and Klar (2008) are the first to provide an intraday analysis of liquidity and price discovery in the European carbon futures market by investigating estimated transaction costs in the now-agreed largely inefficient Phase I of the EU-ETS. They use the Engle and Granger (1987) VECM framework to determine the price process leader between two major platforms in the EU-ETS, they show that the European Climate Exchange (ECX) leads the price discovery process ahead of Nord Pool. Their paper is important in that they employ intraday data. Mizrach and Otsubo (2011) also investigate the initiation of price discovery between two platforms, this time between the Bluenext spot market in Paris and the ECX futures market in London. They use Hasbrouck (1995) and Gonzalo and Granger (1995) information share estimation approaches. They report that the ECX is responsible for about 90% of share of combined price discovery for the two platforms.

In a study using identical methodologies to Benz and Klar (2008), Rittler (2012) examines price discovery and causality issues in the early part of the Phase II. The study aims to identify the price leader between the spot traded from Bluenext, Paris and futures contracts traded on the ECX, London. The two studies are similar not only in techniques but in the direction of investigation. Benz and Klar (2008) focus on price leadership between two platforms (ECX and Nord Pool) in the EU-ETS, and Rittler (2011) on price leadership between two instruments (spot and futures contracts). Cason and Gangadharan (2011) conduct a laboratory examination of price discovery in linked emissions trading markets. They find improvements in price discovery and efficiency as a result of intermediation between linked markets. This holds some relevance to this thesis because the EU-ETS has already been linked to countries outside the EU (Iceland, Liechtenstein and Norway) and EUAs created by those countries are traded on the ECX platform. There are also talks on-going to link up with the Australian and New Zealand versions of CO<sub>2</sub> cap and trade schemes in 2015. Finally on liquidity, Frino et al. (2010) examine liquidity and transaction costs in the EU-ETS using intra-day data from the ECX using quarterly computations, their results show general improvement in liquidity over the course of Phase I and the first two quarters of Phase II.

There are several studies relating to Rittler (2011) in their examination of links between the spot and futures contracts. Uhrig-Homburg and Wagner (2007) employ daily data from Phase I to determine price discovery measures for both spot and futures, the study suggests that futures lead the price discovery process. Daskalakis et al. (2009) explore the links between spot and futures by modelling EUA price dynamics using stochastic processes in Phase I. They find that inter-phase banking restrictions is associated with inconsistencies in futures pricing during Phase I. Futures pricing only conforms to the cost of carry model on intra-phase basis only. This finding is supported to some extent by Joyeux and Milunovich (2010) since they show that long-run links exist between spot and futures in Phase I, they report intertemporal links for spot with two futures contracts tested. Daskalakis and Markellos (2008) earlier show that the market in Phase I did not conform to weak-form efficiency. The authors suggest that the lack of efficiency could be due to banking restrictions and immaturity of the market in Phase I. Montagnoli and de Vries (2010) concur with this assessment of the Phase I market. They show that Phase I was an inefficient experiment, with thin trading leading to huge bias for EMH; the study goes on to examine trading in the very early period of the second phase and report significant improvements in market efficiency.

A different stream of literature studies several factors as contributors to price formation: Christiansen and Arvanitakis (2005), Mansanet-Bataller et al. (2007), Alberola et al. (2008) and Bredin and Muckley (2011) using daily data, explore the effects of changes in energy fundamentals on daily EUA returns in the EU-ETS. Their reports suggest that pricing in the EU-ETS is driven by the fundamentals tested. Miclăuș et al. (2008) apply event study using the AR(1)-GARCH(1,1) model to examine the effect of regulatory events such as NAP and VER announcements on EUA prices. They report that all cumulated abnormal returns obtained are not statistically significant, hence market participants in Phase I were able to anticipate future market conditions. Mansanet-Bataller and Pardo (2007) also apply event study methodology to examine effect of regulatory events, their results imply that announcements have impacts on EUA prices in Phase I. Indeed, Hintermann (2010), using a market that expresses permit prices as a function of several variable; suggest

that prior to a price crash that occurred in April 2006<sup>1</sup>, the price of carbon permits were driven by policy rather than marginal abatement costs. Fezzi and Bunn (2009) employ a VAR procedure and present results implying that electricity prices are jointly influenced by shocks in carbon prices. They show that a 1% increase in the price of carbon resulted in an increase of 0.32% in UK electricity prices during Phase I. Nazifi and Milunovich (2010) also report links between electricity and carbon (as well as between carbon and natural, and carbon and oil), however their results also indicate that the no long-run relationship could be established between carbon prices and coal, oil, natural and electricity.

The foregoing discussions set the background for this thesis' examination of the interrelated issues of price discovery, liquidity and price efficiency in the EU-ETS. Since a number of studies (as discussed in the last four paragraphs) have attempted an explanation of some of these issues in Phase I of the EU-ETS, I focus my attention on Phase II. There is indeed a huge literature gap on intraday evolution of price discovery and liquidity in both Phases I and II. If the markets have tended towards maturity in Phase II, one would expect minimal serial correlation over the day, hence in order to infer on microstructure properties of the market, intraday analysis of the market microstructure is needed. At this point this is missing. My thesis thus attempts to fill the gap. In the following paragraphs I set out in some detail the topics addressed in each chapter with regards to research questions, objectives, key methodologies, important results and general contributions.

The First chapter aims to provide a background to the subsequent chapters by undertaking a descriptive and critical analysis of the EU-ETS and related market design issues respectively. The chapter underscores the economic importance of the EU-ETS as the world's largest emissions trading scheme and its significance to the evolution of global climate change policy.

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<sup>1</sup> The price collapse was due to unorganised release of the first set of emission verification results in Phase I. The incident is discussed in Hintermann (2010), Daskalakis et al. (2011) and Bredin et al. (2011).

Chapter 2<sup>2</sup> answers four research questions on the market microstructure of the EU-ETS: 1) What is the impact of trading activity (executed volumes) on the price discovery process; 2) How does price evolve during regular trading hours and the after hours period; 3) What is the association of liquidity with the price discovery process and price efficiency in the EU-ETS; and 4) How does trading activity impact informational efficiency of carbon futures prices? Since fundamental shifts occur in the market composition (trading activity measures) between the normal trading hours and the after-hours period, I analyse intraday tick-by-tick data from the ECX, using standard microstructure methodologies in conducting the analyses. First, I investigate the distribution of information asymmetry across the periods by using the Huang and Stoll (1997) spread decomposition model. The distribution of adverse selection costs suggests that the after hours market is populated mainly by informed traders. With this background information, I progress to analysing distribution of price discovery in successive stages by using the Weighted Price Contribution (WPC) and Weighted Price Contribution per Trade (WPCT) measures. The results show that most of the price discovery takes place during the normal trading day, however on per unit time basis more information is incorporated in prices during the after-hours than during the normal trading day. Finally, Biais et al.'s (1999) unbiasedness regressions are applied to determine the level of price efficiency on the platform, 16 regressions each are estimated for the four carbon futures. All 64 regressions imply that there is higher price efficiency in the after-hours market; they also indicate that price efficiency is associated with liquidity since the most liquid instruments show the highest level of price efficiency. Indeed the most liquid instrument, the Dec-2009 futures contract, according to the results, enjoys a high level of price efficiency across the whole periods. The results obtained here are of significance to all market participants, especially the uninformed compliance traders who need to understand the intraday evolution of the market composition in order to reduce their information (price discovery-related) risk or adequately seek compensation for carrying those risks.

Chapter 3<sup>3</sup> answers the research question on whether several identified variables determine the impact block trades have on prices of carbon financial instruments on

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<sup>2</sup> Ibikunle et al. (2012) is based on sections of chapter 2.

<sup>3</sup> Ibikunle et al. (2011) is based on sections of chapter 3.

the ECX. The chapter thus investigates the determinants of price impact of block trades over a 40-month period on the ECX by using regression analysis. This is a very important issue for market participants since an increasing proportion of trades are now taking place on platforms rather than OTC (see Kossoy and Ambrosi, 2010; Linacre et al., 2011) The six determinants examined are selected on the basis of submissions from previous works in the price impact literature. I focus on three established price impact types: Permanent, temporary and total price impacts as defined in literature (see Holthausen et al., 1990; Gemmill, 1996; Frino et al., 2007). Different trade dependencies are employed to develop a complete picture of block trades impact; these include dependencies/effects based on trade sign, time of day and trade size variations. The results obtained show varied divergence with existing evidence obtained from equity platforms. For example, there is a general lack of price impact on account of block trades unlike on equity platforms; the results also suggest that contrary to the evidence from earlier studies, widening trading spreads are not associated with significant price impact. These and other findings can be due to the general price run up experienced on the ECX during the period covered by the data, since Saar (2001) suggest that block trades executed on the back of a price run up blunts price impact. The findings from this chapter are significant to all classes of traders in the EU-ETS considering the rising proportion of exchange based block trades to OTC. Participants will be assured by the fact that price impact on account of block trades is limited. This also implies that arbitrage-induced opportunities are virtually non-existent in the market thus potentially boosting compliance trader confidence.

In chapter 4<sup>4</sup>, I use event study methodology as outlined by Campbell et al. (1997) to test for abnormal returns on carbon futures trading on the European Energy Exchange (EEX). Specifically, I report on the impact of four events: The official commencement of trading in Phase II, the release of emission verification results for the 2007 and 2008 compliance years, and the announcement of the Commission Regulation (EC) No 994/2008 of 8<sup>th</sup> October 2008 (a policy event aimed at improving the security of EU-ETS platforms). I extend the study to include analyses of volume changes and liquidity effects associated with the events using time series regression

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<sup>4</sup> Ibikunle et al. (2011) is based on sections of chapter 4.

and bid-ask spread liquidity proxies respectively. The results suggest that carbon futures liquidity and trading volumes improve after the start of trading in Phase II, and that the improvements are sustained over time for about 90 days. Based on these results, the tighter caps and new rules introduced for the Phase II are associated with the observed market quality improvements. For the release of emissions verification announcements; the results show that the events are correlated with significant carbon futures liquidity and trading volume improvements, which are sustained to varying degrees over 90 days after the announcements. The results are perhaps due to the fact that the announcements confirm that the market was net short for the 2007 and 2008 compliance periods. This is important since the announcements come after net long results had been announced for the previous two years (2005 and 2006). Contrary to results obtained for other events, the policy event examined is linked with declining carbon futures liquidity and volumes on the short term (-5, +5 days). Gradual improvements over the 90-day period examined are however reported as well. The results for this event is probably due to its connection with loss of market confidence, since the text of the announcement suggests that the Commission viewed the platforms' state of security as being below the required standard. The results from this chapter are of significance to mainly policy makers; for example, regulators can gain insights into market reaction to policy announcements by forecasting effects on microstructure properties of carbon futures instruments. The microstructure properties of financial instruments give indications of market quality as explained in earlier paragraphs of this section.

Chapters 2, 3 and 4 each focuses on one issue as stand alone studies. The next chapter provides the background to these chapters.

# 1. Background

## 1.1. Introduction

Emissions trading via cap and trade was established as a viable policy instrument by the work of Montgomery (1972). Employing a static framework under perfect market conditions, they observe that, for participating firms in an emissions constrained economy, there is minimum cost equilibrium. Rubin (1996), using optimal control theory also show that the equilibrium price for greenhouse gas emission permit corresponds to the costs due to marginal abatement measures if firms are allowed to bank and borrow emission permits (see Springer, 2003 for a review of results gathered from 25 models on marketable emission permits). Emissions' trading thus provides the avenue for firms to fund emissions reduction programmes through the sale of excess permits earned by investing in abatement measures in the first place. Also firms are able to reduce emissions by applying the most economical means of doing so. Emissions' trading as a key component of the Kyoto Protocol now plays an important role in the drive to reduce global emissions. The Kyoto Protocol, an international framework with 192 parties came into force in January 2005. The framework has spurred the growth of a multi-billion dollar sector for emissions trading. The European carbon market has accounted for driving more than 95% of global market share for any given year since 2006 (see Linacre et al., 2011).

The Kyoto Protocol provides three mechanisms with which participating countries can achieve their emissions targets. The mechanisms include International Emissions Trading (IET), the Clean Development Mechanism (CDM) and Joint Implementation (JI). The three mechanisms provided for by the Kyoto Protocol are representative of the different statuses of its signatories. Under Kyoto Protocol, the 37 industrialised countries and the EU accepted binding reduction targets over a five-year period (2008-2012). The parties can use the mechanisms provided in achieving their individual targets. Article 4 of the Protocol allows for parties to accept emission reduction targets as part of a bubble. The EU, in accepting emission reduction targets as a unit, is considered a bubble. Trading currently takes place electronically with the setting up of an International Transaction Log (ITL), which has been operational since



2007. For now, no successor framework has been agreed on at the United Nations level.

IET between countries requires that both nations must have accepted Kyoto Protocol sanctioned caps. For JI, however, both must have signed on the Protocol in principle but need not have accepted caps in greenhouse gases emissions. Nations with economies in transition to a market economy can be helped to attain energy efficiency through the JI mechanism. The JI is essentially a mechanism for helping nations with economies in transition to a market economy attain a competitive level of energy efficiency. JI thus aids the flow of investment in green technology and projects from Western Europe to the east of the continent (see Babiker et al., 2002; den Elzen and de Moor, 2002).

Although some developing countries are bigger emitters of greenhouse gases than developed countries, the developing nations did not accept caps under the Kyoto Protocol. This is a particularly controversial aspect of the Kyoto Protocol, especially in relation to China which is the largest emitter of greenhouse gases but is still regarded as a “developing” country (see Gregg et al., 2008; Minx et al., 2011). The absence of emissions reduction quotas for the developing nations is due to the fact that, historically, industrialised countries emitted most greenhouse gases. This is in keeping with the fairness doctrine of the United Nations Framework Convention on Climate Change (UNFCCC). By virtue of their status under the Kyoto Protocol, the developing nations are not eligible for IET and JI; hence, the design of CDM to act as a channel for transfer of green funds and clean technologies to developing countries. However, it has been argued that this could lead to unchecked migration of emissions from capped countries to uncapped ones such as the developing countries. Countries that rejected caps such as the United States can also benefit from this loop-hole (see Barrett, 1998).

The EU undertakes to reduce its emissions by 8% below the 1990 levels by employing mainly the International Emissions Trading (IET) mechanism. Since Europe continues to dominate the emissions permit market, and will do so for the foreseeable future, this thesis focuses on EU-ETS platforms. It is believed that the future of global cap and trade policy is dependent on the success or otherwise of the

EU-ETS. The EU-ETS is designed as a compulsory cap and trade scheme where participating installations have a legal requirement to lower their emissions in accordance to set caps. However, these participating installations have the opportunity to buy emissions permits to offset exceeding those caps. The tri-status nature of the Kyoto Protocol has already been embedded in the EU-ETS by the use of the EU Linking Directive (Directive 2004/101/EC). This directive creates a direct 'link' between EU emissions and global climate policy, essentially ensuring that emission credits from the CDM and JI can be submitted in lieu of emission reductions towards the EU's reduction target (see Flåm, 2007).

The use of permit trading is not novel to the Kyoto Protocol or the EU-ETS. Until the start of the EU-ETS, the most prominent example of emissions permit trading has been the United States Acid Rain programme. The Environmental Protection Agency (EPA) has employed emissions trading as a policy tool to achieve emissions reductions since 1992 (see Joskow et al., 1998). There is no shortage of publications examining the operational value of this programme with most concurring on its success. Joskow et al. (1998) and Albrecht et al. (2004) concur on the efficiency of the SO<sub>2</sub> market and the fact that it is a market that meets its target of reigning in SO<sub>2</sub> emissions. The allowances are traded as spot, forward and options, underscoring its liquidity. A fundamental difference between the SO<sub>2</sub> market and the EU-ETS is that the latter has never restricted banned intertemporal trading.

A number of theoretical and empirical contributions (a large proportion of these have been discussed in five paragraphs in the introduction) provide evidence of the EU-ETS market characteristics; hence the nature of this market is becoming quite apparent. EU-ETS phase-dependent issues are related and these connections remain largely unexplored. This chapter provides a further discussion of these issues from economic, policy and financial regulation perspectives as background to the empirical studies in this thesis. The issues reviewed span the first two phases of the scheme (2005-2012), the review thus sets the tone for the subsequent chapters of the thesis.

The remainder of this chapter is arranged as follows: Section 1.2 briefly examines the concept of cap and trade/emissions trading, section 1.3 provides some background analysis of the EU-EUS with respect to regulatory and trading issues. Section 1.4

builds on section 1.3 by critically evaluating the impact of the regulatory issues on trading and market quality in the EU-ETS, section 1.5 briefly examines future policy outlook and section 1.6 concludes.

## **1.2. Cap and Trade: The Emissions Trading Option**

The design of cap and trade is based on regulating aggregate emissions by putting a price on a target gas. Permission to emit the regulated gas is issued as allowances. Emissions trading contrasts taxation in one respect, the regulator decides only a cap, and then the market decides price on the target gas based on scarcity forced by the regulator's cap (supply) and aggregate demand for right to emit the gas. In such a scheme, the regulator is not directly responsible for fixing the price of emissions; however, they can influence the pricing of the targeted gas through the introduction of policies. For example, in the EU-ETS, there is a percentage of emission allowances held in reserve (called new entrants reserve) that can be allocated in order to influence pricing. Market fundamentals, such as supply and demand forces and exogenous shocks are thus involved in emission permits price discovery process (see Burtraw et al., 2011).

The issuance of the allowances can take the form of free allocation based on historical emissions patterns of an industry (grandfathering), through auction or a combination of both to any degree. The companies and installations involved in this scheme reserve the right to trade their emission allowances, giving them market based options on meeting the volume targets set by the regulator. A company can be a net seller if it finds it to be more cost effective to reduce emissions than to buy allowances; it can then sell off its surplus allocations to participants with excess emissions. On the other hand, if purchasing allowances improves firm competitiveness, the firm may opt to be a net buyer (see Boemare and Quirion, 2002; Böhringer and Lange, 2005).

### 1.3. Structure of the EU-ETS

At this time there are only three identified phases of the EU-ETS. The three-year pre-Kyoto commitment trial period (2005-2007) is the so-called Phase I, while the Kyoto commitment period itself (2008-2012) is known as Phase II. The EU has decided to proceed to a third phase starting from 2013 to 2020. The climate change agreement signed by the conference of parties in Durban, South Africa in December of 2011 has affirmed this decision.

The EU-ETS is the main element of the EU's climate change policy. The EU adopted a 'burden sharing agreement' (Council Decision 2002/358/CE) allowing it to re-allocate emissions reduction targets within its member states so as to avoid stifling vital economic growth in the less wealthy countries. This consequently leads to the setting of more demanding targets for the larger European economies such as Germany and the UK. The member countries are responsible for identifying the installations affected within their borders under the aggregated reduction target. The additional ten countries (the so-called ascension nations) as well as Iceland, Liechtenstein and Norway (non-EU European countries) also participate in the EU-ETS (see Williams and Kittel, 2004). Croatia will be joining in 2013.

About 12,000 installations with minimum generating capacity of 20 megawatts (MW) in a number of sectors within the EU are brought under the EU-ETS.<sup>5</sup> A total of 2.2 billion tCO<sub>2</sub> were distributed to the affected installations in Phase I (see Dodwell, 2005). Combined, these installations account for approximately 40% of the EU's total greenhouse gas emissions (see Hawksworth and Swinney, 2009). There are several key differences in the operational features of the three phases and these are summarised in Table 1.1.

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<sup>5</sup> These sectors include electricity generators, mineral oil refineries, coke ovens, ferrous metals, glass, ceramic products and cement manufacturers to glass and pulp producers. Electricity generators are however the leading CO<sub>2</sub> emitters. By Council decision, the aviation sector joined the EU-ETS (see Directive 2008/101/EC).

**Table 1.1 Phases of the European Union Emissions Trading Scheme (EU-ETS)**

The table compares the three phases of the EU-ETS by using regulatory issues as basis of comparison. Phase I ran between 2005 and 2007, Phase II started in 2008 and is expected to run until the end of 2012 and Phase III starts in 2013 and will run until 2020.

<b>Variables</b>	<b>Phase I</b>	<b>Phase II</b>	<b>Phase III</b>
<b>Gases targeted</b>	CO <sub>2</sub> only	CO <sub>2</sub> only	CO <sub>2</sub> , Perflouorocarbons and Nitrous Oxide
<b>Allocation system</b>	Allocation based on grandfathering.	Up to 10% of created permits can be auctioned, the balance auctioned or held in reserve for new entrants.	Twenty percent auctioning in 2013 with gradual rise to 70% in 2020. The degree of auctioning varies by industry and country.
<b>Proportion of green house gases under scheme</b>	40%	40%	50%
<b>Banking regulations</b>	Intra-phase banking only (France and Poland allowed conditional banking to Phase II)	Inter-phase banking allowed	Inter-phase banking allowed
<b>Allocation Planning</b>	National Allocation Plans (NAP)	National Allocation Plans (NAP)	European Union-wide allocations
<b>Penalty for default</b>	€40 per EUA not submitted plus submission of missing EUA in subsequent compliance year	€100 per EUA not submitted plus submission of missing EUA in subsequent compliance year	Penalty per EUA not submitted is aligned with the European Price Index, plus submission of missing EUA

### **1.3.1. Emissions Permits Creation and Use**

For each phase of the scheme, each participating country develops a National Action Plan (NAP) stating the reduction in greenhouse gases emission required for each installation over a stated period (usually a phase, then divided into annual targets) as per the burden sharing agreement. The amount of emission permits created is subject to approved emissions quota in the plans. The NAP thus also creates a finite amount of emission permits called European Union Allowances (EUAs). Each EUA grants the holder the right to emit one tonne of CO<sub>2</sub> (tCO<sub>2</sub>). In the first two phases of the EU-ETS, only CO<sub>2</sub> emissions are targeted. By creating a limited volume of EUAs, a cap is placed on the volume of CO<sub>2</sub> emissions during the period.

At the firm level, in Phase I, 95% of EUAs created was allocated free to installations and 5% held in reserve for new entrants (The new entrants reserve is aimed at providing some period of flexibility for new companies and installations entering into the scheme). In Phase II, up to 10% of the total available is being auctioned in EU countries to various degrees. In the third phase (Phase III), EU member states are expected to auction an increasing proportion of EUAs, starting from 20% of the total stock of EUAs in 2013 and increasing it annually in order to reach 70% by 2020. The eventual objective is to attain full auctioning at the firm level by 2027 post-Phase III (see Directive 2009/29/EC).

All EU national registries are linked and are connected to the EU Commission's Community Independent Transaction Log (CITL), which chronicles all changes to EUA rights by stakeholders at both national and continental levels. Consequently, the national registries record of firm level trading activities is replicated on the CITL as every trade within a member state is registered at a relevant national registry. Annually, by March 31, all installations under the EU-ETS are required to provide an externally audited report to the relevant emissions regulator. This report will include the volume of CO<sub>2</sub> emitted in the course of operations during the preceding compliance year. By April 30, the installations then have to submit an amount of EUAs equal to the volume emitted during the year. The submission actually involves

the deletion of the appropriate number of EUAs from the installations' accounts with the relevant registries.

There are measures aimed at dissuading failure to comply: In Phases I and II, the penalty includes €40 and €100 fine respectively for each EUA not surrendered for deletion as well as the eventual surrendering of the EUA during the next compliance year. In Phase III, the penalty will see increases based on the European index of consumer prices (see Directive 2009/29/EC). This new provision amends Article 16:4 of the EU Directive 2003/87/EC. As with the two previous phases, the missing EUAs will still be delivered in the next compliance year, the penalty notwithstanding. The provision that requires submission of missing EUAs, along with the respective penalties, serves to ensure that a price ceiling is not inadvertently set for EUAs. This ensures that the markets still get to determine EUA prices without the regulator's interference as the weight of penalties may be construed as a signal of the regulator's projected upper bounds for the market and hence may limit potential price appreciation. The EU Commission has repeatedly maintained that EUA prices will be determined purely by demand and supply forces.

Project emissions permits are also allowed for submission in the EU-ETS. The 'linking directive' (Directive 2004/101/EC) sanctions that Certified Emission Reduction units (CERs) and Emission Reduction Units (ERUs) from CDM and JI project sources respectively can be surrendered in place of EUAs in a ratio of 1:1 for compliance purposes. However with very strict percentage based limits.

Based on the limits set in the respective member states' NAPs, EUAs are annually grandfathered (and also auctioned in Phases II, III) to the installations (and the market). This annual allocation usually takes place by the end of February, giving a two-month interval between allocation and the time when installations provide their annual emissions reports. Ideally, the allocations are for the future compliance year, the implication however, is that the installations can borrow future permits to offset the preceding year's compliance (see Daskalakis et al., 2011). Borrowing future EUAs is permitted for a year only and must be within the phase. EUAs can be banked (stored for future use) from previous years for future compliance. This regulation applies only to Phases II and III of the EU-ETS on a EU-wide scale.

During Phase I most member states prevented the banking of allowances from 2007 to 2008. This is logical owing to the fact that emissions reductions during 2005-2007 (Phase I) cannot be used in achieving the Kyoto commitment period targets. The EU member states were at liberty to allow banking between Phases I and II of the EU-ETS. However, only France and Poland allowed this with strong restrictions stemming from the requirement to secure EU Commission's authorization and banking limits (see MEMO/06/452 of the European Commission). In Poland and France, installations were allowed to bank the maximum of the difference between their primary allocation and their verified emissions. The permits acquired on the market were not eligible for banking (see Dufour, 2006; Uhrig-Homburg and Wagner, 2009).

#### **1.4. Critical Phase-Dependent Issues Arising From EU-ETS Design and Regulations**

##### **1.4.1. The Problem with Ban on Intertemporal Trading**

The ban placed on transfer of permits from Phase I to Phase II mentioned in section 1.3.1 and highlighted in Table 1.1 does have some far reaching implications; the discussions here lead up to these consequences. A number of studies, such as Joskow et al. (1998), Schmalensee et al. (1998), Stavins (1998), Butzengeiger et al. (2001) and Svendsen and Vesterdal (2003) examine the design and market structure of cap and trade from economics and policy viewpoints. From these studies, it is clear that the success of the cap and trade system is predicated on a number of factors. Liquidity, diversity of industries involved and the flexibility in developing emission reduction strategies are vital requirements for a successful scheme. Firms must be able to reduce emissions only when it is more economically efficient to do so rather than purchase emission permits in the market. The overriding consideration should be to ensure compliance with capped levels at the least possible cost, hence the need for flexibility (see also Rubin, 1996; Kling and Rubin, 1997; Schennach, 2000; Schleich et al., 2006). A greater level of efficiency and success of the system can be ensured when the scheme permits the transfer of emissions allowances between periods (intertemporal trading). This means allowing firms borrow permits from future



periods and the transfer of excess permits to future periods for the purpose of compliance.

Despite the preponderance of this perspective among academics prior to the start of the EU-ETS, the EU opted to ban intertemporal trading between Phases I and Phase II of the EU-ETS. A major reason was because the first phase of the scheme was just a trial phase aimed at fine-tuning the scheme for the Kyoto commitment phase (Phase II). Had banking of allowances been permitted; the EU's Kyoto target may not have been achieved with excess liquidity building in Phase I. However, allocations in Phase II could have been made to account for the excess quantity available from Phase I, helping avert excess liquidity and market quality decline issues in both phases. The decision not to allow intertemporal trading eventually led to significant losses in market value for derivative instruments with delivery dates near the close of Phase I. This is because they do not retain market value for the next phase (see Daskalakis et al., 2009).

#### **1.4.2. The Problem with Initial Allocation in Phase I**

The method of allocation of start up allowances on emissions trading schemes has always generated contentious debate since the passing of the US Clean Air act and such debates have only increased with the setting up of the EU-ETS. In the allocation of initial allowances, the volume released into the system is very crucial in ensuring the credibility of the scheme. Tight caps are in place to engender relative scarcity thereby building a measure of price elasticity (see Boemare and Quirion, 2002; Vesterdal and Svendsen, 2004; Böhringer and Lange, 2005; Neuhoff et al., 2006). In Phase I of the EU-ETS, grandfathering was the method of allocation, although in theory auctioning is more desirable. Auctioning at a price sends a strong indication of the value placed on the allowances by the regulator and fosters price signal transparency. Price transparency improves information dissemination and builds confidence of a clear market structure and price discovery processes (see Grubb and Neuhoff, 2006; Neuhoff et al., 2006). Auctioning is also a revenue generator. Revenue generation can give governments more options in discretionary spending.

Research and development of green technology is often funded and, in the event of emissions leakage, vulnerable industries are often supported to retain competitiveness.

The release of CO<sub>2</sub> into the atmosphere is a restricted activity in the EU (an emissions constrained economy) and this translates into costs for firms through the purchase of permits. The cost of permits in a pure economic view should be passed on to consumers. The power sector in the EU is the sector impacted the most by EU-ETS. If the costs of permits are passed on to consumers, it is expected that power prices will increase in relation to the costs of those permits (see Linares et al., 2006; Kara et al., 2008; Reneses and Centeno, 2008). However, since EUA levels were net long due to over-allocation of allowances in Phase I, no increases in costs should occur between 2005 and 2007 on account of the EU-ETS. In addition, allocations were made to the companies involved through grandfathering and no costs were incurred through the allocation process. It is understood that costs could still be incurred under grandfathering, but only if EUAs had been net short, which they were not. *Ceteris paribus* Phase I should not have caused price increases in the power market. A number of studies report price increases in electricity costs to the consumer, supposedly as a consequence of carbon costs. For example, Fezzi and Bunn (2009) report that in Phase I, a 1% increase in the price of carbon resulted in an increase of 0.32% in UK electricity prices (see also Sijm et al., 2005; Sijm et al., 2006). The free allocation of emission permits thus potentially creates windfall opportunities for electricity producers.

The general conclusion that can be made on the allocation mechanism in Phase I is simply that it fell short of desired results. The policy aim of reducing emissions through changes in institutional and individual power use contingent on rising costs of power was largely not achieved. The impact of carbon prices on electricity prices however suggests that this is achievable. The allocation mechanism in Phase I was ill advised and poorly executed and this led to installations having no use to invest in emissions abatement measures. Having stated this, Phase I must have had some impact on emissions in the latter stages because the emission reports for 2007 according to the EU Commission show a 1.6% decline in EU aggregate emissions. The approaching economic slowdown of 2008 could have also contributed to the decline in emissions. Auctioning or a combination of both auctioning and

grandfathering are the preferred alternatives to pure grandfathering (see Boemare and Quirion, 2002; Böhringer and Lange; Sijm et al., 2006). A combination approach has been adopted in Phase II, with an even more aggressive posture expected in Phase III.

### **1.4.3. Carbon Price in the EU-ETS**

Carbon price symbolises the incorporation of the costs of emitting carbon into production processes in an emissions constrained economy (Labatt and White, 2007). Theoretically, the price of carbon is expected to be correlated to the marginal costs of abatement of greenhouse gases emissions reduction (see Hintermann, 2010; Rubin, 1996). Market frictions and exogenous impacts such as restrictions on banking and borrowing (from a policy perspective) however readily complicate the pricing of carbon; this thesis examines some of these issues.

Analysing emission permits pricing requires an understanding of what EUAs behave like in trading: commodities or other financial asset classes, or perhaps they are different to both classes. As EUAs are electronically generated records on EU member states' registries, they have features that straddle several financial asset classes. Although EUAs share features with commodities and they can be regarded as commodities in terms of delivery as an underlying of derivative contracts, delivery of EUAs is virtually 'risk-free' in comparison with more traditional commodities such as agricultural produces and petroleum products (Daskalakis et al., 2011). The transfer of EUAs only requires a recorded transfer from one holder to the other at the national registry, hence are traded and delivered in a way similar to regular financial futures. Under close scrutiny, EUAs exhibit characteristics of traditional commodities in that classic supply and demand influences are fundamental drivers of their price structure. As with many commodities, EUAs can also be classed as a factor in production. Demand for EUAs is driven by demand for energy (see Alberola et al., 2008) and factors that also influence the demand for other, more traditional, commodities. These include factors such as the state of the economy, lifestyle and taste alterations etc. The supply end of the EUA is almost entirely influenced by policies of regulating agencies. International treaties based on scientific developments then in turn influence regulators.

With this rather slightly more complex web of non-market factors, carbon pricing should hardly correlate with financial asset classes. Daskalakis et al. (2009) explore the question of correlation of CO<sub>2</sub> emission allowances with other asset classes and find no significant correlation with major asset classes, their results suggest carbon instruments could be used for investment diversification. There are striking similarities between CO<sub>2</sub> emission allowances and financial assets that cannot be overlooked however. For example, as it is with financial assets the possession of CO<sub>2</sub> emission allowances endows a right to an underlying benefit. In the case of EUAs, the benefit is the permission to pollute to a certain degree. Also similar to financial assets, EUAs are not liable to quantity losses, they need not be physically stored, they have unrestricted tradability and their pricing can be determined by supply and demand. Regulations can influence upper bounds of EUAs and this can force the development of different properties from those of traditional financial instruments. The fundamental characteristic affected by regulations is the pricing of carbon, thus exhibiting stochastic properties at variance with other financial instruments/assets. In contrast to financial asset classes such as bonds and stocks, interests or dividends cannot be paid on CO<sub>2</sub> certificates.<sup>6</sup> Primarily, CO<sub>2</sub> emission allowances are instruments of compliance (see Uhrig-Homburg and Wagner, 2007; Daskalakis et al., 2009), as a result, their pricing should reflect the cost of compliance (see Hintermann, 2010). Although energy related variables represent the strongest link in the determination of compliance costs, there are suggestions that linkages may exist between carbon prices and financial markets. For example, Koch (2012) reports variable association between carbon financial instruments and financial asset returns; the next section thus considers the trading evidence for correlations during the global financial crisis.

#### **1.4.4. Impact of the Global Financial Crisis on the EU-ETS**

During the first trading year in Phase II (2008), transactions on the EU-ETS were valued at US\$101.49 billion (€74.56 billion) representing an 87% growth rate on the previous year, with more than three billion EUA spot, future and option contracts

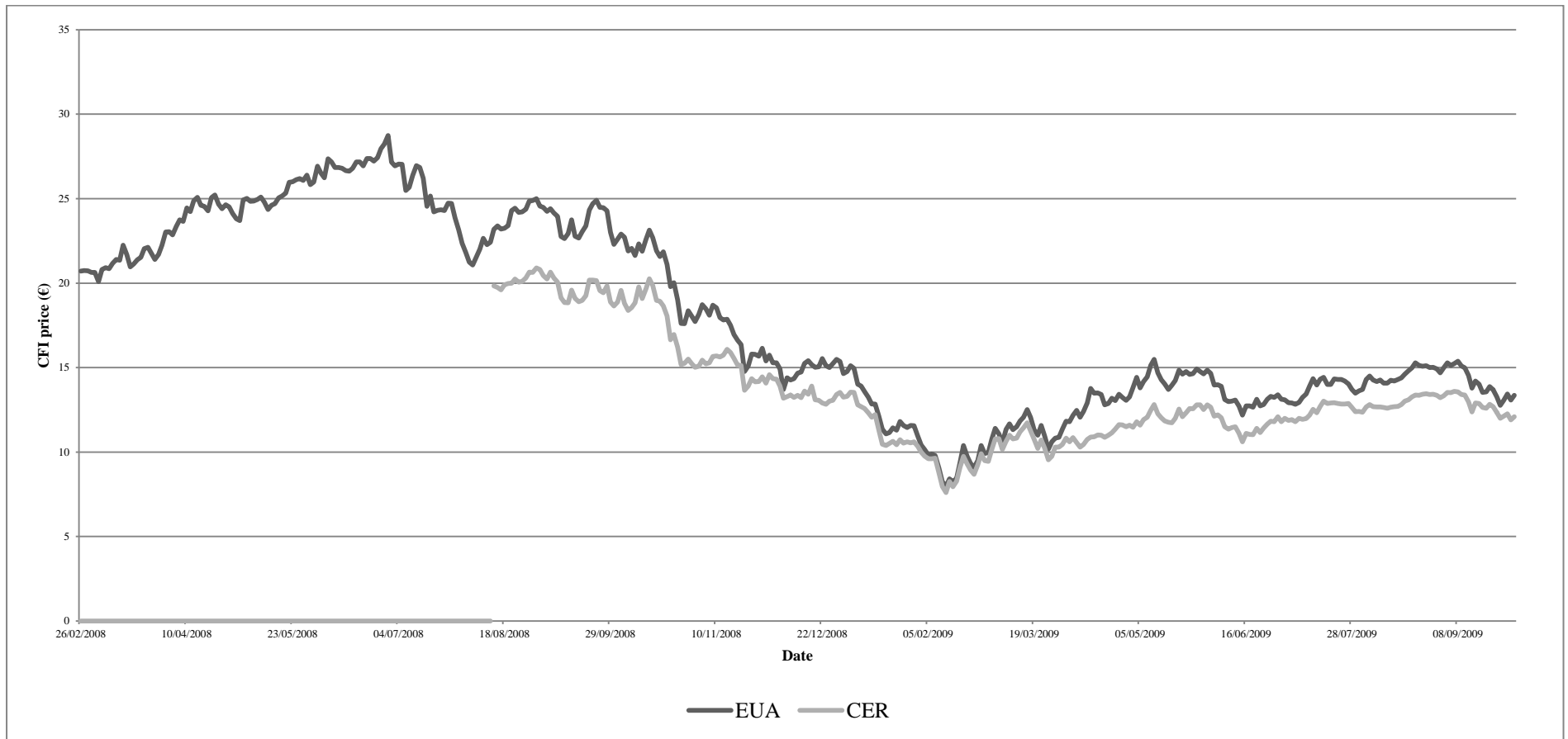
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<sup>6</sup> CO<sub>2</sub> certificates, emission allowances, emission permits are used interchangeably in this thesis.

traded. In 2008, the recession in Europe and the rest of the developed world forced significant reduction in demand for major commodities such as housing, cars etc. This resulted in a lower demand for cement, steel and other raw materials. Consequently manufacturing and building projects stalled, leading to lower energy consumption. The need to purchase EUAs is based on energy/power and oil consumption (see Alberola et al., 2008; Mansanet-Bataller et al. 2007) and, as power consumption dropped, the demand for EUAs declined. This led to a sharp drop in carbon prices. The spot price during the year plunged 75% over a period of 8 months from a record level of €28.73 in July 2008 to lowly €7.96 on February 12 2009 (see Capoor and Ambrosi, 2009). The decline was not limited to spot trading; declines as dramatic as the one recorded on the spot trades also occurred in secondary CER (see Figure 1.1). Considering this link of carbon permit price with a global economy bellwether commodity in oil, it is not surprising that Koch (2012) report variable correlations of carbon futures with financial asset returns.

### Figure 1.1. Response of Carbon Financial Instruments to Recession

The figure illustrates the variations in prices of carbon financial instruments trading in the EU-ETS, to the recession of 2008-2009. The chart is plotted with data sourced from BlueNext, Paris. The data spans 26/02/2008 to 30/09/2009.



The decline in demand for CO<sub>2</sub> allowances meant that corporations accumulated more grandfathered allowances than was needed. This, coupled with the tightness of credit, led to a huge sell off to raise money. The higher rate of supply by these heavy industries, the ditching of long positions by investors (who were not compliance buyers) and the decline in demand in the aftermath of the economic slowdown resulted in a rapid fall in EUA prices and those of its derivatives. During this period, daily and monthly records for spot transactions were broken in a flurry of trading by corporations in search of liquidity in a difficult credit market. Most of the increased trading was reportedly done in the spot market and this accounted for 36% of all transactions in the EU-ETS in December 2008. This is a major contrast to an initial low of 1% in the first half of the year (Capoor and Ambrosi, 2009).

However, as the worst of the recession passed and spare capacity started being used up, consumption began to rise and this led to the gradual return of market confidence. The rising consumer confidence in energy commodities and other asset classes observed in the second half of 2008 was mirrored in emissions permit prices in the EU-ETS, another piece of evidence that carbon prices are correlated with the energy commodities (see Christiansen and Arvanitakis, 2005; Mansanet-Bataller et al., 2007; Alberola et al., 2008 for reports on carbon price relationship with energy commodities). The price recovery in April 2009 can also be attributed to the need for compliance buyers to submit their EUA allowances for the 2008 compliance period; this generated more buying and market liquidity. In 2009, the EU-ETS accounted for 96.46% of global allowances trades (valued at \$122.8 billion). This is with a trading volume of around 6.326 billion tCO<sub>2</sub> worth US\$118.5 billion (€88.7 billion), up from approximately 3.1 billion tonnes (worth \$101.49 billion) in 2008. The market value in 2009 represents an 18% improvement over 2008; this came despite a 42% dip in EUA prices over the same period. By 2010, the market appeared to have recovered from the recessionary impacts of 2008. In 2010, the value of total EUA traded climbed to US\$119.8 billion (more than 84% the global carbon market value) and the EU-ETS driven share of the global market increased to 97% (Linacre et al., 2011). This underscores the economic significance of the EU-ETS.

#### **1.4.5. Regulatory Risk Issues in the EU-ETS**

Five issues have come to the fore since the launch of the EU-ETS in 2005 and these underscore the underlying market risks in the EU-ETS. The first issue relates to the EUA price collapse of April 2006 (see Bredin et al., 2011; Daskalakis et al., 2011; Hintermann, 2010). The over-allocation of permits to ensure that domestic firms retain competitiveness vindicates the concerns already expressed about both market foundation risks and market confidence risks. The price collapse also relates to information asymmetry as a result of disorderly release of information to the market by political regulators with little knowledge of the complexities of the market (Frino et al., 2010).

The second issue is the now infamous Carousel VAT evasion strategy. Many firms took part in this, effectively affording themselves free and temporary funds through culling of VAT imposed on spot trading of EUAs across the EU. Simply put the strategy involves the collection of VAT on commodities, which is not passed on to the regulatory authorities. In a number of European countries, when buyers and sellers of a commodity are in different jurisdictions, the importers (buyers) are either not subject to paying VAT levies or are only required to pay up at a later time, which is usually one to three months. The seller is, however, required to pay the local VAT to the buyer. Conversely, if both the buyer and seller are domiciled in the same country, the VAT is payable by cash on the date of transaction. EUAs exist only as records on national registries and are therefore easily transported across borders. VAT exemptions provide VAT-based funding for the actors but they lead to loss of revenue to the governments. In late 2009, Europol estimated that more than €5 billion had been lost by EU countries as a result of the fraud scheme. Issues such as this greatly affect the market integrity of the carbon market. The most exposed countries, such as France and the United Kingdom, acted to restore market integrity through unilateral measures. These include reverse charging mechanism and criminal prosecution with arrests made in the United Kingdom, France, Norway and Spain. In September 2009, the EU proposed other measures (see Linacre et al., 2011 for details and further discussions).

The third issue relates to recycling of CERs already surrendered for compliance by installations. A significant case is the sale of surrendered CERs by Hungary in March 2010. The EU responded by modifying the registry rules to prevent future occurrences (see Kossoy and Ambrosi, 2010).



Fourthly, there have been a number of controversies over submitted NAPs by some countries. The European Commission, exercising its privilege as EU-wide regulator of the EU-ETS, suppressed the issuance of EUAs from the NAPs of Estonia and Poland. These two countries dissented and appealed to the European Court of First Instance and the court promptly annulled the Commission's decision. The authority of the Commission has suffered as a result of this annulment and this is anticipated to have consequences for the market operation.

Finally, the biggest risk so far faced by the EU-ETS is insecurity of national registries. In January 2011 it was discovered that EUAs worth more than €45 million had been stolen from certain registries in the EU. This unprecedented discovery led to the temporary closure of some national registries and the suspension of spot trading in the EU-ETS. In the months following the discovery, the European Commission embarked on an EU-wide rehabilitation and improvement of national registry security systems (Linacre et al., 2011).

The events enumerated above may have dented the credibility of transactions in the EU-ETS, but they have also validated expectations of a maturing market, showing that the EU-ETS is becoming fully integrated with the European economy. This is based on the fact that these types of occurrences occasionally occur in mainstream traditional markets and have come to be expected in valuable markets, hence the enforcement of financial regulations.

## **1.5. Current Affairs and the Future**

Current international developments underline not only the growing international importance of emissions trading, but also the need for clear evidence on how well the EU-ETS is functioning. Understanding the microstructure of the EU-ETS is therefore important since it can inform policy decisions regarding upcoming international emissions trading schemes. Recent events, especially the important deal reached at COP 17 in Durban, suggest that governments in other regions of the world are already progressing towards emissions trading. In the event that a global ETS is established in order to effectively counter climate change, the scheme is likely to be anchored on the EU-ETS infrastructure if the scheme can be proven to be effective. As an indication of developments in the future, three non-EU countries: Liechtenstein, Norway and Iceland have already linked their cap and trade structures to the

EU-ETS. Australia has also begun talks with New Zealand on linking their schemes in 2015. In principle, the EU is open to the prospect of inter-regional linking of cap and trade schemes. Linking various ETS structures around the globe will likely precede a global ETS. The EU-ETS will be vital to this development, especially with respect to provision of required market trading volumes and liquidity. Also Jacobsen (2011) reports evidence of improvement in carbon-offset voluntary purchases by individuals in the United States even in the absence of a national framework on climate change. This potentially underscores the argument for the application of cap and trade on the downstream in the United States rather than the upstream (see for example Hobbs et al., 2010; Hanemann, 2009).

## **1.6. Conclusion**

The EU-ETS is a multi-billion dollar market deserving of attention from finance and economics researchers. In this chapter, the economic significance of the EU-ETS is examined in detail along with several phase dependent issues. It also provides a descriptive analysis of the EU-ETS as background to empirical studies reported in chapters 2, 3 and 4 of this thesis. The chapter generally conveys the view that the Phase I experiment in the EU-ETS was not as successful as policy makers planned. However, since the EU-ETS remains the main driver for global emissions trading, its success is critical to any global advances with respect to climate change policy. Studies examined in this chapter suggest that emissions trading schemes have the potential to work as informationally efficient financial markets if the right combination of factors is in place, chief among these being the right structure to ensure carbon prices equal to the marginal abatement costs of CO<sub>2</sub> (efficient price signalling). The question then is: Is the EU-ETS (informationally) efficient? Daskalakis and Markellos (2008) provide some answers to this question for Phase I, they suggest that the market did not confirm to weak form efficiency. In the next chapter, I explore informational efficiency in Phase II using high frequency data from the largest carbon trading platform in the world with some interesting results. The results here are very important in that they are the first set to show the intraday evolution of the price discovery process. They provide investors, compliance traders and policy makers with the information required to engage with the market. The results will benefit most those who lack sophisticated trading strategies, with the information provided; they can avoid trading with potentially well informed participants in order to avoid pricing risks.

Several other market microstructure issues that can give insights into the state of maturity of the EU-ETS remain largely unexplored for Phase II, and even for Phase I. Liquidity and diversity of industries involved in the EU-ETS are also of very high importance in order to maintain market quality (liquidity and efficient price discovery). In chapter 4, I examine the association between the advancement of liquidity and the onset of trading in Phase II of the EU-ETS. The liquidity effects of other relevant effects are also examined. Since power companies and other large entities are compliance traders in the EU-ETS, one would expect regular institutional trading patterns such as block trading. Therefore, in chapter 3 of my thesis, I investigate the impact of these trade classes on the scheme's largest trading platform, the ECX.

Finally, the EU-ETS has consistently released emission verification results showing net short emissions positions since the Kyoto commitment phase commenced (the liquidity impact of these are examined in chapter 4). The verification results are the strongest sets of evidence that the scheme may already be achieving its primary purpose. If the following chapters of this thesis can show further evidence of the improving maturity of the EU-ETS, then it can be proposed as a template to build a global platform for climate change action through emissions trading mechanism. The challenges of this are enormous. The task of aligning the interests of countries from economically diverse regions and that are at different stages of economic growth will not be easy. It will require significant political capital and goodwill, however it starts with empirical evidence that the first experiment (the EU-ETS) has been successful. This thesis therefore contributes to this gap in knowledge i.e. providing evidence of market quality in the EU-ETS.

## 2. Price Discovery and Trading After Hours on the ECX

### 2.1. Introduction

It has been more than 135 years since the Walrasian theory of general equilibrium (price formation) was first considered; yet what determines price in markets remains a very active area in financial economics research. The impact of changes, not limited to technological improvements in the market place, since the late 1980s altered the way markets operate, leading to a number of studies on stock market price discovery and its determinants (see among others Barclay et al., 1990; Flood et al., 1999; Chan et al., 1995b; Easley et al., 1996; Easley et al., 1997). Then, the introduction of after-hours trading (AHT) further altered the landscape. In this respect the works of Barclay and Hendershott (2003, 2004) have been acclaimed. Barclay and Hendershott (2003) investigate the AHT periods of before market opens (BMO) and after market closes (AMC) on the NASDAQ, creating the first comprehensive insight into how these two periods contribute to price formation on the stock exchange and their contrasting features. A number of other contributions were previously made to BMO price discovery through analysis of non-executed orders and non-binding quotes prior to opening. Madhavan and Panchapagesan (2000) and Stoll and Whaley (1990) analyse contributions that activities of professional traders make to the opening price on the New York Stock Exchange (NYSE). Biais et al. (1999) and Davies (2003) investigate the effect of non-binding BMO orders on the Paris Bourse and the Toronto Stock Exchange respectively, they show how the orders reflect learning in the markets. Ciccotello and Hatheway (2000) and Cao et al. (2000) examine the price discovery process by means of non-binding market maker quotes.

More recently, He et al. (2009) investigate the efficiency of price discovery in a 24-hour U.S. treasury market showing that the overnight trading period is a more important component of the treasury price discovery process than previously thought. This is a clear departure from the findings of Barclay and Hendershott (2003) on contributions of overnight trades to price discovery. In their analysis of AMC trading, price contributions and discovery after the release of firm earnings (during AHT), Jiang et al. (2012) seem to arrive at the same conclusion as He et al. (2009). Confirming the clout of after hours trading, they find BMO and AMC periods contribute 36% and 60% of price discovery respectively on earnings announcements days despite comparatively low trading volumes (see also Greene and Watts,

1996). Macro economic announcements as well have been linked with exchange rate jumps by Andersen et al. (2003), Almeida et al. (1998) and Goodhart et al. (1993). Andersen et al. (2003) also report news impact asymmetry in that bad news has stronger impact than good news.

This study on AHT and price discovery differs from the aforementioned works in one respect. The investigations are conducted in a unique market, exchange traded permits market. In this market the motivation for AMC trading year round is difficult to grasp since permits are submitted to authorities for compliance purposes only once a year. Although permits have value, they are ‘created’ as records by regulatory authorities with the mechanism to influence prices if the need arises. Moreover, for emissions markets, transaction costs are incurred at various levels of trading. Additional costs incurred on information, seeking agreeable terms on block trades and reporting compliance records to authorities do contribute heavily to transaction costs (see Stavins, 1995; Gangadharan, 2000; Cason and Gangadharan, 2011; 2003). Additional elements of transaction costs can result in loss of trading volumes when trades are made unappealing (Kerr and Máre, 1998). These issues are not all pertinent to regular markets. Further, permit markets are not always vanilla, there are variations to their operations, unlike markets for more traditional instruments with a high level of rules synchronisation. Grull and Taschini’s (2011) study of the potential of changes slight variations in trading rules can make to market properties, proves this point.

There is a growing body of work on price formation in the EU-ETS, most of these are based on Phase I data (see thesis introduction section, see also Rittler, 2012; RotfuB, 2009 for overview of the studies). These studies, do not investigate intraday evolution of price discovery or efficiency of price formation and their relationship to trading activity. To the knowledge of this researcher, this is also true for the wider emissions permit market. These issues are addressed in this study using Phase II data of exchange traded permits.

Fundamental shifts<sup>7</sup> possible in composition of informed and uninformed traders during the transition from RTH to the AMC period<sup>8</sup> provides an avenue to employ some of the

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<sup>7</sup> Changes, during the day and across days, are in small increments in traditional markets according to Admati and Pfleiderer (1988), Madhavan et al (1997), Foster and Viswanathan (1993).

techniques used in previous AHT studies in this analysis of the carbon permit market. This chapter is aimed at answering the following questions: First, what is the impact of trading activity on the disclosure of information in carbon futures and does this have any effect on the time of disclosure? Second, does the AMC period in carbon futures reveal anything? Third, does liquidity inform price discovery and information efficiency in carbon futures market? And fourth, what is the impact of trading activity on informational efficiency of carbon futures contract prices?

The major contribution to the existing literature on price discovery in AHT comes from this thesis' analysis of a unique market which exchanges traded carbon permits. The EU-ETS is the world's first large experiment for CO<sub>2</sub>-based emission trading and policy makers in other regions throughout the world are keenly watching it. Its success or otherwise will be a factor in determining whether a global emissions trading scheme will be adopted as a mechanism for limiting greenhouse gas missions. The findings here on intraday evolution of price discovery during the regular trading hours (RTH) and AHT period will determine if the EU-ETS market is efficient, and therefore if it can provide a platform for a global market led approach to tackling global warming via the reduction of carbon emissions.

The contributions of this study go beyond adding to literature on market microstructure. Much of the microstructure properties of the European carbon futures market are still being unravelled, the results can therefore inform trading patterns especially for compliance buyers of carbon instruments. Regulators can also gain insights into the effect of certain trade instruments used in the market and on the trading process. Also, participants currently trade bilaterally in the AMC period on the ECX with little documented knowledge on the informational risks associated with this; this study stands to shed more light on the associated risks.

The analysis mainly compares different intervals/periods of the normal trading day/RTH and the AMC period. Microstructure studies establish that information asymmetry reduces over the course of the day (see Glosten and Harris, 1988; Lin et al., 1995; Huang and Stoll, 1997; Madhavan et al., 1997 and others). The study is predicated on the role played by information

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<sup>8</sup> AMC period on the ECX is restricted to Exchange for Physical (EFP) and Exchange for Swaps (EFS) trades only. A detailed description is provided in section 2.2.

over the RTH and the AMC periods, hence the first step taken is to analyse the information asymmetry levels across the periods using the Huang and Stoll (1997) spread decomposition model. Adverse selection costs and effective spreads for each of the periods are obtained. These provide the basis to launch this chapter's investigations.

The results presented in this chapter reveal that more contracts are traded per minute in the AMC period than during the normal trading day. Using the Huang and Stoll (1997) spread decomposition model, the study discovers that higher levels of information asymmetry are present during the AMC period/hour than at any other interval per hour during the normal trading day, the normal trading day is however responsible for the highest share of price discovery at over 71%. This is not surprising since there is ten hours of normal trading day and just one of AMC trading. The research also finds evidence that contribution to price discovery is a function of liquidity. Less liquid contracts prove the highest contributors to price discovery, even though they are informationally inefficient. The analysis of exchange traded permits thus agree for the most part with existing literature in that little trading can generate disproportionate price discovery and that liquidity is associated with informational efficiency. Also as in other studies, the least traded instruments contribute the largest proportion of price discovery in the AMC. The aggregate findings suggest that a mandatory cap and trading scheme such as the EU-ETS is an efficient way of reducing carbon emissions. The efficiency of the EU-ETS could provide a basis for the introduction of a mandatory global market led approach to reducing carbon emissions.

The remainder of this chapter is structured as follows. First, in section 2.2, the trading environment on the ECX is discussed as background to the analysis. Section 2.3 discusses the sample selection and describes the data. Section 2.4 describes the econometric methods employed and also presents and discusses the results of the empirical analyses and section 2.5 concludes.

## **2.2. The Trading Environment on the ECX**

Trading in physically delivered EUA futures commenced in April 2005. The contracts are offered on a quarterly expiry cycle (March, June, September and December) up to June 2013. EUA futures contracts with annual (December) deliveries for 2013 until 2020 have also been

introduced. The underlying for each ECX EUA contract is 1,000 EUAs. The trading system is electronic and continuous, initiates at 7:00hrs and ends at 17:00hrs UK local time from Monday to Friday. The maturity date for the contracts is the last Monday of the traded month and physical settlement occurs three days after expiry. In 2010, EUA carbon permits accounted for more than 84% of global carbon market value. Of these, approximately 73% are traded as futures contracts (see Kossoy and Ambrosi, 2010; Linacre et al., 2011). The ECX platform is the market leader in EU-ETS exchange based carbon trading with more than 92% market share. This includes OTC trades registered on the platform to reduce counterparty risk. The December maturity contracts roughly represent about 76% of daily transactions on the platform hence form the basis of this study's investigations. The global dominance of the ECX platform has attracted participants from beyond Europe. In 2009, about 15% of trade volume on the platform was from traders domiciled in the United States (Kossoy and Ambrosi, 2010).

Carbon Financial Instruments (CFI) trading on the ECX platform is done electronically on the ICE platform. ICE Futures Europe platform can only be accessed by members and this is strictly for the purpose of placing orders for execution. All trading orders placed on the platform and their corresponding executions are anonymous. The electronically executed trades go through the so-called Trade Registration System (TRS) for account allocation.

For most major futures trading platforms operated by Intercontinental Exchange (ICE) Europe, there is a pre-open trading period of 15 minutes to allow for participants to place early orders in preparation for another trading day. The market opens for an initial period from between 6:45am and 7:00am. These fifteen minute period on the ECX platform hardly records any executed orders over the ten month period covered by the dataset in 2009 (February-November), only 12 trades with a combined contract volume of 700 were recorded on the exchange. Trading takes place between 7:00hrs and 17:00hrs on the ECX platform. Presumably, no officially sanctioned trade is allowed beyond this point, however allowance is provided for registering of Exchange for Physical (EFP) and Exchange for Swaps (EFS) trades. EFP and EFS trades are only permitted for EUA and CER Futures contracts. This can be reported using an electronic facility called the ICEBLOCK on the platform. The Exchange officially requests that these trades be registered up to 30 minutes after the close of official trading each trading day except for the day of expiration of the traded contract. Reporting of EFP/EFS trades on the exchange however occurs up until about 6:00pm regularly on the days



covered by the sample as acknowledged by ECX officials. The trades are essentially bilateral trades that in theory require no market maker quotes to execute.

The trades are usually registered by the buyer who charges the trade to the seller. The seller then matches the trade by confirming it (Non-crossed Trade). It is possible for prices of AMC EFP and EFS trades to fall outside the high and low points in the RTH (or beyond the biggest price shift from the previous close's settlement price) since the prices are not revealed until after the close, but this requires approval from the ICE Futures Europe Compliance Department prior to registration. The maximum price deviation however is still pegged at €1.00.

EFP/EFS trades provides an hedging option using ECX EUA futures contracts, in just a single transaction i.e. the seller of emissions permits becomes the buyer of ECX futures contract and the buyer of the permits, the corresponding seller of ECX contracts. They also allow for the substitution of Over the Counter (OTC) swap positions with corresponding ECX contracts. For these trades, there are no obligatory market maker quotes during the AMC. Members (brokers) can execute these trades on behalf of clients on the ICE platform, and the brokers are still under obligation to obtain the best deals on behalf of their customers as their fiduciary duty demands.

Spreads and consequently trading costs during AMC are expected to be larger than during the RTH. It is expected that volume of reported trades AMC will be very low (daily average) in comparison to the RTH. However, since these trades are likely to be executed by professional traders aiming to balance their positions at the end of a trading day, the volume per trade should be higher than during the RTH. The absolute necessity to satisfy optimal portfolio balancing therefore trumps the disadvantage of low liquidity and possibly higher trading costs.

## **2.3. Data**

### **2.3.1. Sample Selection**

Two datasets from the ECX platform are employed for the full spectrum of analysis. The first, which is the main dataset employed, comprises of all intra-day tick-by-tick ECX EUA

Futures contracts trades on the ICE platform from February 2009 through to November 2009. The dataset contains date, timestamp, market identifier, product description, traded month, order identifier, trade initiation (bid/offer), traded price, quantity traded, parent identifier and trade type. This dataset is provided directly by ICE Data LLP, London for the purpose of this doctoral research. The dataset contains 15 CFIs available on the ECX (futures contracts and futures spreads).

The second dataset is the end of day (EOD) data for ECX Futures from February 2009 through November 2009. From here, the daily settlement price, daily low price, daily high price, and daily first price are acquired. Also extracted are daily volume (for all trade types) and daily weighted average price from the dataset. This dataset does not contain any records for futures contract spreads, which are present in the first dataset.

11 of the CFI available are eliminated by applying the following conditions: 1) Both datasets must provide trading records from February 2009 through November 2009 for the selected CFI; 2) As the analysis is based on the comparison of RTH to AMC, the CFI must be tradable during both periods in an EFP or EFS trade; 3) The CFI must also be traded for at least 20% of days during both periods between February and November, 2009.

The ECX tick dataset includes the trade initiator identifier, hence trades could be identified as buyer or seller initiated trades. For the AMC trades however, the challenge is that all trades are identified as buyer initiated by default since the trades are usually registered by the buyer who then alleges it to a seller. The TRS records trades based on the order submission and if it is matched, the order submitted first is the initiating order and becomes the initiator. This is misleading in the case of the AMC trade registration; hence to overcome this challenge, the tick test is used for classifying AMC trades. For robustness, results based on tick test are compared with those based on actual exchange identifier codes for the normal trading day, the results are very similar. Trades occurring at a price greater than the prevailing trade midpoint are classified as buyer initiated and those at a price lower than the prevailing midpoint as seller initiated. If the current and the previous trades are the same price, then I classify using the next previous trade. Analysis of the tick rule by Lee and Ready (1991) and Aitken and Frino (1996a) suggest the tick rule's accuracy to be in the excess of 90%, with accuracy levels as low as 74% in some instances. Finally, the 12 trades recorded before 7:00hrs London local time in the sample are excluded from the final dataset.

### 2.3.2. Sample Description

The ECX platform is the only exchange where official AMC trading is recorded in the EU-ETS and the trading is quite thin, averaging a total of 60 trades and 2,700 contracts per day. The contracts in the sample represent 99.998% of total AMC trades recorded on the platform between February and November 2009. Trading in the EU-ETS in comparison to more established financial and commodities derivatives markets is very thin. AMC trades averaged about €37,000,000 in value per day or 14.58% of the daily total Euro value between February and November 2009. AMC recorded trading is limited to between 17:00 and 18:00 hours GMT. As noted by Porter and Weaver (1998), block trades on NASDAQ in the past were posted late (after-hours) after having been executed during the RTH. This does not hold for the sample as the trading system is electronic and the participants have real time access to input their trades at anytime during the RTH. Further, the bilateral nature of the EFP and EFS trades ensures that the trades even though agreed during the trading are unknown to the market until it is registered on the ICE platform. Finally, the order Ids acquired by the trades evidenced that they all entered the system after the close of trading, which is as far as trade execution time can be approximated, moreover, an order on ICE platform is only executed when it is matched by a corresponding buy/sell order.

Table 2.1 reports RTH and AMC trading activity summary. The results show daily average estimates for individual contracts and the full sample averages per contract per day. The trading volume is skewed towards one contract (December 2009) throughout the 211 days covered by this study. About 83% of the AMC trades in this sample are recorded for the December 2009 contract. This is not unusual in the EU-ETS; I report the same phenomenon for the EEX in chapter 4. Joyeux and Milunovich (2010) as well as Mizrach and Otsubo (2011) also report the same trend for the ECX at various time in Phases I and II respectively.

The most traded contract, the Dec-2009, averages 50 AMC trades per day (with a market value of about €26,000,000 per day), while the other four contracts in this sample account for an approximate average of ten trades per day. Trading activity for the lower trading contracts show a steep fall to an average of about 6 contracts per day for the closest trading one (Dec-2010) to the Dec-2009 contract. The Dec-2013 contract has an average less than 0.12 trades recorded during the AMC period. As a result of this extremely low level of trading activity,

the contract and the others with lower trading AMC activity are excluded from further analysis (with the exception of trading activity analyses in this section). The inclusion of the Dec-2013 contract gives a more accurate picture of trading activities but due to low level of transactions it could not be include in more robust analyses.

**Table 2.1. Trading Summary**

The table shows summary of trading activities of After Market Closes (AMC) and Regular Trading Hours (RTH) periods for five contracts trading on the ECX platform. The contracts are the highest volume trading ones of the contracts eligible for AMC trading. The data covers the trading period from February 2009 through to November 2009. The table includes estimates for daily average euro volume, number of contract trades executed per day, average contract volume per day and percentage of days with trading for the AMC period. The RTH period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.

	AMC				RTH		
	Number of Trades	Volume (€ '000)	Contract Volume	% Days with trading	Number of Trades	Volume (€ '000)	Contract volume
<b>Dec-09</b>	50.23	25907	1957.07	97.22	1239.61	129263	9775.74
<b>Dec-10</b>	5.66	4603	328.18	90.28	142.33	46571	1674.24
<b>Dec-11</b>	1.49	1916	131.03	63.89	52.51	19669	681.29
<b>Dec-12</b>	3.18	4214	267.79	79.63	84.65	19769	1279.83
<b>Dec-13</b>	0.12	193	11.40	7.41	1.09	515	32.85

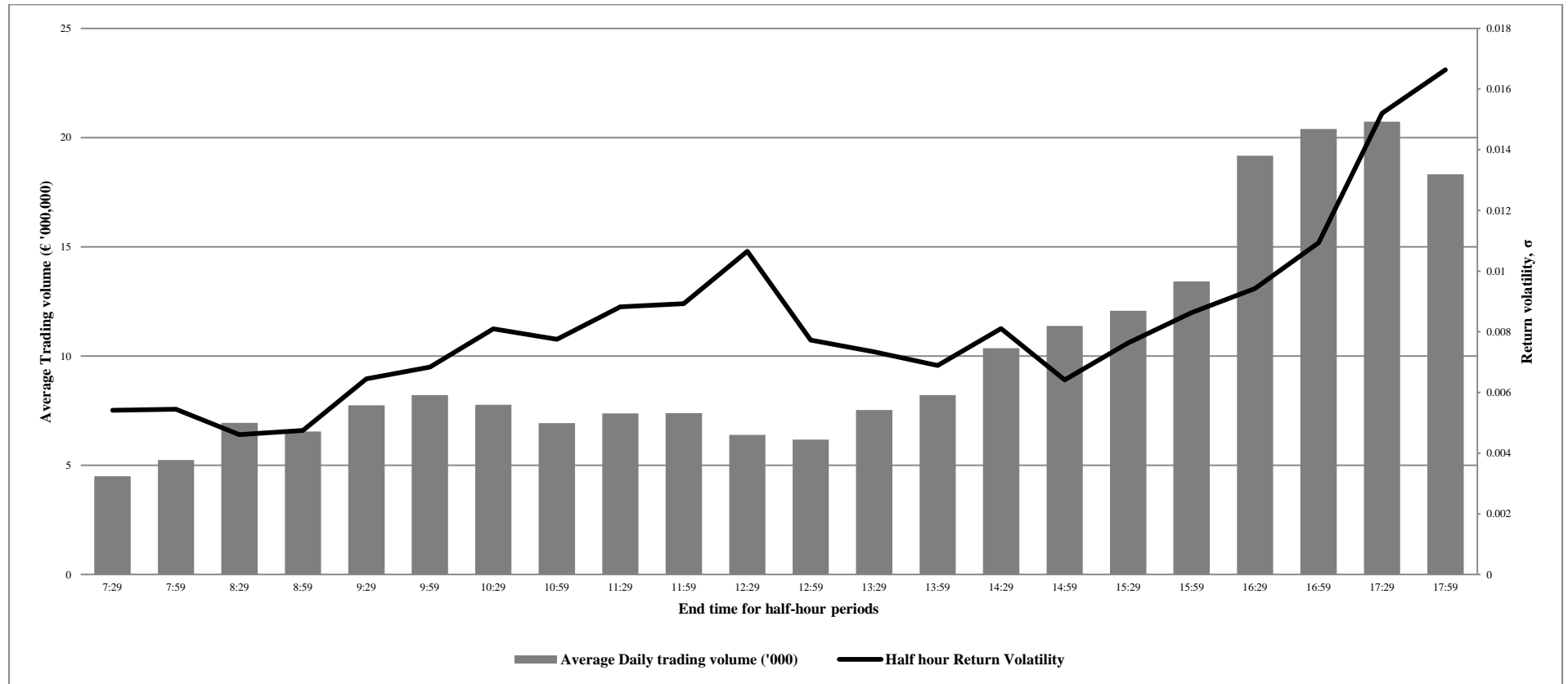
## 2.4. Results and Discussion

### 2.4.1. Trading Volume and Volatility

Figure 2.1 depicts for each half-hour interval, the average daily trading volume and average return volatility. Volatility is computed as the standard deviation of half-hour returns on the platform, it is estimated using the December 2009 contract only due to huge gaps in trading cycle of other contracts. Trading on the ECX displays an inverted S-shape rather than the now familiar U-shape pattern identified with derivative markets (see Chan et al., 1995a; Gwilym et al., 1997). Also in a clear contrast to previous studies, the most active period during the RTH is not the opening period. The closing stages of the RTH and the one hour AMC period are the most active periods on the ECX volume-wise. Indeed, the largest Euro volume of trades per half-hour is recorded in the first half hour of AMC trading. This volume then holds steady for the concluding half-hour of the AMC trading period shedding only about 11.63% of volume from the preceding half-hour period. Volatility and trading volume display high levels of correlation (Spearman's Rank Correlation Coefficient of 0.74) as shown in Figure 2.1. The high level of correlation corresponds to evidence from most equity platforms, for example Barclay and Hendershott (2003) high correlation levels for NASDAQ.

**Figure 2.1. Trading Volume and Volatility**

The figure shows average daily trading volume and volatility for every half-hour period of the Regular Trading Hours (RTH) and After Market Closes (AMC) periods for the December maturity contracts (2009, 2010, 2011, 2012 and 2013) trading on the ECX platform. The data covers the trading period February 2009 through November 2009. Volatility is computed as the standard deviation of the half-hour contract return and is calculated for the December 2009 contract only. Volatility was estimated using the December 2009 contract only due to huge gaps in trading cycle of other contracts. Volatility was however also calculated using the other contracts as well but excluding their trading gap periods, the pattern is highly similar. The RTH period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.

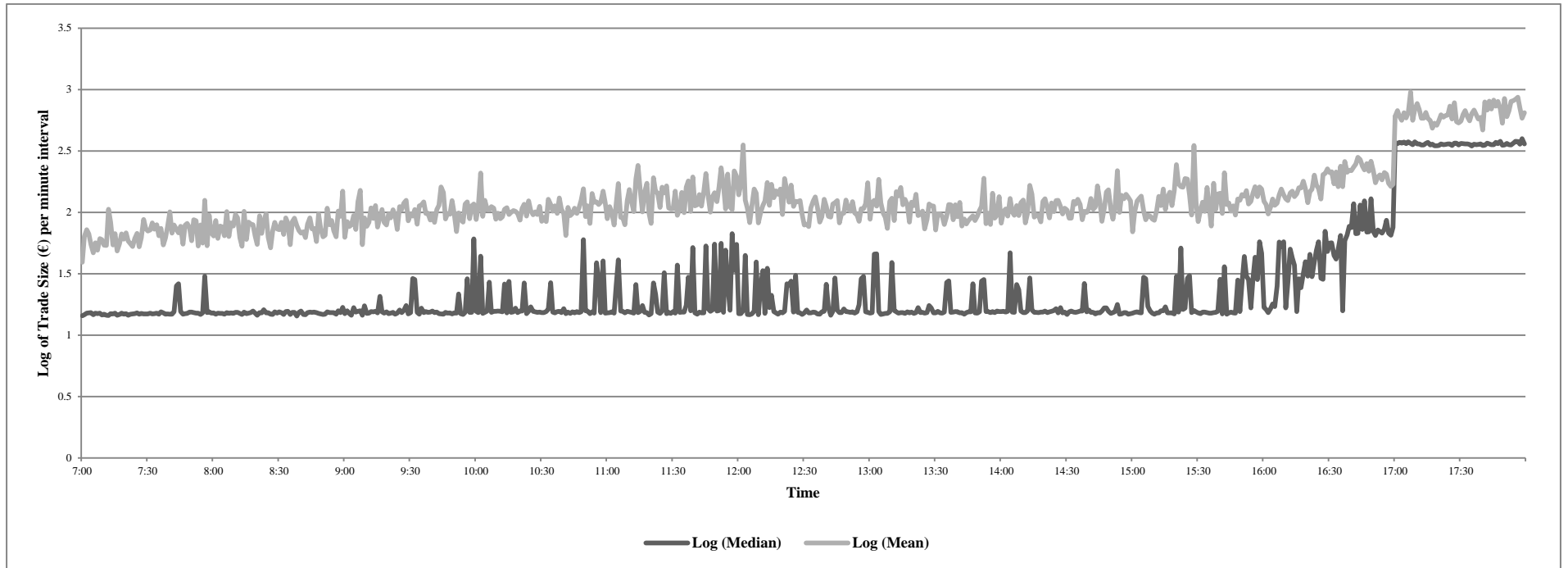


While the AMC trading volume on the ECX platform is inconsistent with previous studies (see Barclay and Hendershott, 2003), larger AMC mean and median trade values are consistent with them. Figure 2.2 shows log-transformations of median and mean trade sizes at one-minute intervals, the log scale is used because of the large variability of the trade sizes after-hours. As expected, very steep rises in the mean and median sizes of trades are observed after the close. Mean estimates nearly quadruple in the first minute of AMC trading and then peak at almost €955,000 on 17:07hrs. Trading values during the remainder of the session hold up competently. The final minute of trading has a mean value of nearly €600,000 which is almost twice the highest mean estimate at any point during the RTH.



**Figure 2.2. Log Median and Mean Trade Size**

The figure shows the logarithmic conversion of median and mean trade sizes over the entire trading periods of Regular Trading Hours (RTH) and After Market Closes (AMC) for the December maturity contracts (2009, 2010, 2011, 2012 and 2013) trading on the ECX platform. The data covers the trading period February 2009 through November 2009. The RTH period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.



### **2.4.2. Motivation for Trading During the AMC: Liquidity or Information?**

There are no significant differences between the rules governing the registration of trade on the ECX during RTH and AMC periods. However trading in the AMC it is a privilege open only to members with access to the ICEBLOCK facility. Based on this, it is expected that the market at that time will be primarily composed of professional traders or traders acting on behalf of their clients. The question then arises, why leave it that late? Why is the largest value of trading per minute reserved for this period of the day? EFP and EFS trades can be reported at anytime of the day with less of the time constraint that is the one-hour AMC market.

Microstructure studies assume two main types of traders, both holding idiosyncratic risks: the first are those who trade in search of liquidity, their aim is inventory control and portfolio rebalancing (especially at the end of each regular trading day). The second set of traders comprises of those trading on private information unknown at the time of trading to majority of the market. Since participation in the market is motivated by different reasons, it is assumed that these two classes of traders will have varying degrees of activeness in the AMC session.

According to literature, information asymmetry and uncertainty over fundamentals usually decrease over the course of a trading day (see Kyle, 1985; Madhavan et al., 1997; Foster and Viswanathan, 1990; Easley and O'Hara, 1992; Easley et al., 1997; Huang and Stoll, 1997). In addition, Madhavan et al. (1997) also find that trading costs increases as RTH progresses. Barclay and Hendershott (2003) note that public and private information accrue overnight when no trading takes place. Indeed for the ECX there is a non-trading interval of 12 hours and 45 minutes between the end of the AMC market and the 15 minute pre-open at 6:45hrs London local time. This interval is longer than the 11-hour 15- minute combined trading period afforded by the platform. It is a safe bet that some information akin to the carbon or ancillary markets could have accumulated during the no-trading period, hence a high level of information asymmetry is anticipated for the early trading period and this is also expected to decline from then on and over the course of the normal trading day.

Further, the EU-ETS is an unusual market with many twists and turns, fuelled by the controversy that is climate change science. A lot of the trades are aimed at offsetting emissions by market participants hence these would be based on information on the anticipated level of emissions. Installation production levels determine emissions, so there is an expectation of a market heavy on informed trades especially in the AMC period. The expectation includes a higher level of informed trading for the later maturity contracts than in the Dec-2009 contract. Emission permits are not submitted year-round to offset verified emissions positions; therefore trades could also be based on risk hedging and portfolio diversification. If emission permits are for submission to the authorities once a year, it is logical to expect that AMC trading is not an absolute necessity unless there is an advantage to be earned. Uhrig-Homburg and Wagner (2009) argued along the same lines in a study investigating the EUA spot and futures relationship. Much more importantly, the size of the typical EFP/ EFS trades in this sample suggests that these trades will be mainly initiated by institutional and compliance traders who are clearing members of the exchange. Kurov (2008) shows evidence that institutional traders in index futures markets are more informed than other classes of market participants. These reasons lead one to expect that larger spreads and higher levels of informed trading would subsist during the AMC period. Further, previous studies have shown there is higher informed trading during AMC than during RTH (see Barclay and Hendershott, 2003).

For trades motivated by the search for liquidity, the motive contrasts that of those influenced by privately held information. According to Brock and Kleidon (1992), being in possession of a sub-prime portfolio overnight comes at higher costs in comparison with holding an optimal one. This is a huge motivation for market participants who could not complete the optimal balancing of their portfolio during the regular hours to trade in the AMC period. On the ECX, the EFP and EFS trades offer this opportunity.

In addition to expecting higher informed trades in the AMC, it is also anticipated that the first few hours of the RTH will exhibit higher information asymmetry than other periods during the RTH. This is as a result of the information accumulation earlier noted would have occurred during the non-trading period overnight. Although there is higher CFI volume in the AMC period, there will be reduced liquidity, due to reducing number of traders during this period of the day. Based on the foregoing, one can assume that there would be larger spreads than at any interval during the RTH during the AMC period. The superior volume per trade in

the AMC suggests that a substantial proportion of the trades are information induced (see Kraus and Stoll, 1972; Easley and O'Hara, 1987; Chan and Lakonishok, 1993 and others), hence the larger spreads compensate for risk of trading with informed traders.

This thesis thus examines the hypotheses that there is a higher level of informed trading and larger spreads during the AMC trading hour than at any other period during the day by estimating adverse selection information components and effective spreads at different intervals during the day and during the AMC period by using Huang and Stoll's (1997) spread decomposition model. The next section initially explains the intuition behind the main forerunner to the Huang and Stoll (1997) model, the Madhavan et al. (1997) trade indicator model, then explains how the Huang and Stoll (1997) model reconciles it and previous models.

### **2.4.3. Adverse Selection Costs and Spread Analyses**

For financial markets, understanding the microstructure is vital. The use of measures such as bid-ask spread as gauges of liquidity plays an important part in this as literature evolves to harness its descriptive characteristics. Most papers written on measures of market liquidity (and to lesser extent market efficiency) have largely been focused on the bid-ask spread. Danielsson and Payne (2010) identify several reasons for this. The first being the growth of asymmetric information and inventory costs literature in the 1980s (see as examples Ho and Stoll, 1981; Ho and Stoll, 1983; Roll, 1984; Glosten and Milgrom, 1985; Glosten, 1987). Based on these studies, spread estimations became less ambivalent. Another reason is the progress recorded in development of robust estimators for spread components based on the existing theories (see as examples Glosten and Harris, 1988; Stoll, 1989; Hasbrouck, 1991a; Hasbrouck, 1991b; Foster and Viswanathan, 1993). Finally, more often than not, available microstructure databases contain only information on the spread, with little or incomplete information on other measuring components of liquidity.

Madhavan et al. (1997) builds on previous studies to produce a structural model of intraday price formation that incorporates microstructure impacts and revision of trading information shocks. The Huang and Stoll (1997) model (based on portfolio trading pressure) reconciles Madhavan et al. (1997) and preceding models to fully decompose the transaction spread into all of its component elements. The authors provide two extensions of the basic microstructure

model, one of which is based on portfolio trading pressure. This section provides a succinct derivation of the Madhavan et al. (1997) model as well as Huang and Stoll (1997) model extension based on portfolio trading pressure.

#### 2.4.3.1. Madhavan et al. (1997) Spread Decomposition model

The model is an integration of several microstructure influences identified and evaluated in previous works (see Garbade and Silber, 1979; Roll, 1984; Glosten and Milgrom, 1985; Choi et al., 1988; Stoll, 1989). Consider that the trading environment for a risky instrument with time dependent value is a kind of auction-quote driven market. Both a market maker and traders submitting limit orders can provide liquidity in this market. The liquidity providers using any of these mechanisms thus provide bid and ask prices at which they wish to execute transactions. Execution of orders within these quotes is considered plausible.

Denote  $P_t$  as the transaction price at time  $t$  for the stated risky asset with constantly evolving value through time. Also, let  $x_t$  be a dummy variable indicating whether a trade is buyer or seller initiated (+1 if it is buyer initiated and -1 if it is seller initiated). In the event that a trade is regarded as both buyer and seller initiated, then  $x_t$  will take on the value of 0. Denote  $\lambda$  as the unconditional probability that a trade takes place within the quoted spread:  $\lambda = \Pr [x_t = 0]$ . In the same manner, let the assumption hold that buy and sell transactions can similarly occur such that  $E[x_t] = 0$  and  $\text{Var} [x_t] = (1 - \lambda)$ .

New knowledge in form of publicly available announcements bring about the revision of previously held conclusions by market participants, similarly, order flow induced stimulus can affect previously held beliefs. The former, announcements in the public domain can cause revision of held notions without any trading occurring. Let  $\epsilon_t$  represent the evolution of beliefs owing to new information being released to the public domain between the interval  $t-1$  and  $t$  and let the assumption hold that  $\epsilon_t$  is i.i.d. with  $E[\epsilon_t] = 0$  and  $\text{Var}[\epsilon_t] = \sigma_\epsilon^2$ . Also market makers can hold the notion of exposure to adverse selection costs leading to association of an upward and downward modification of held beliefs to buy and sell orders respectively. The reconsideration of beliefs is deemed to be analogous to the uncorrelated order flow, the review of beliefs is said to hold a positively correlated relationship with innovation in the order flow (see Glosten and Milgrom, 1985). The alteration of held beliefs resulting from the order flow can then be written as  $\theta(x_t - E[x_t|x_{t-1}])$ , where  $(x_t - E[x_t|x_{t-1}])$  represents

the shock in order flow and  $\theta \geq 0$  quantifies the permanent effect component of the “order flow innovation”; this is the asymmetric information parameter. Substantial reviews of beliefs with regard to *innovation* in order flow are indicated by large values of  $\theta$ . Madhavan et al.’s (1997) assumption in regard to a fixed size of order is congruous with preceding works (see for example Roll, 1984; Glosten and Milgrom, 1985; Choi et al., 1988; Stoll, 1989; George et al., 1991).

Let the expected estimate of asset based on publicly available information and the trade type (buyer or seller initiated) be represented by  $\mu_t$ . The change in previously held beliefs is then equal to the aggregate of adjustment in beliefs, which is as a result of publicly available information and the innovations in the order flow, such that the expected value of the asset after the trade can be written as:

$$\mu_t = \mu_{t-1} + \theta(x_t - E[x_t|x_{t-1}]) + \varepsilon_t \quad (2.1)$$

Both Madhavan et al. (1997) and Glosten and Milgrom (1985) agree that the bid price is determined by a transaction being seller initiated and the ask price being buyer initiated. Therefore, the pre-transaction ask price at time  $t$  as is denoted  $p_t^a$  and in the same vein the bid price is denoted as  $p_t^b$ . As previously stated, market makers make their quotes with the intention of obtaining compensation for supplying liquidity when required by the market. Denote  $\phi \geq 0$  as cost/unit asset to the market maker due to liquidity provision. The market maker’s recompense to cover the costs of transaction, inventory and adverse selection is then  $\phi$ . Then, the price dependent on the dummy variable  $x_t$  being +1 (the ask price) can be expressed as  $p_t^a = \mu_{t-1} + \theta(1 - E[x_t|x_{t-1}]) + \phi + \varepsilon_t$ . Following after the determination of ask price, the bid price can be expressed as  $p_t^b = \mu_{t-1} + \theta(1 - E[x_t|x_{t-1}]) + \phi + \varepsilon_t$ . The parameter  $\phi$  consequently encapsulates the transient impact of order flow on prices. Orders are carried out outside and at bid and ask prices as well as within them, the general assumption that runs through here will be that the trades are executed at the mid-price:  $(p_t^a + p_t^b)/2$ . The trade price is then computed as:

$$p_t = \mu_t + \phi x_t + \xi_t \quad (2.2)$$

$\xi_t$  is an i.i.d. random variable and has a mean of zero.  $\xi_t$  encapsulates the impact of randomly determined rounding errors due to price disjunction or variability of returns. It should be noted that due to a tendency to round up on buys and down on sells, there is likely to be a structured divergence of  $\xi_t$  from 0. The market maker cost component,  $\phi$  captures this divergence.

It should also be noted that in equation (2.2),  $\mu_t$  is the mean conditioned on the observance of  $x_t$ . Notwithstanding the fact that bid and ask prices from market makers are set prior to the commencement or conclusion of the trades, Madhavan et al. (1997) reason that these prices are still conditioned on the yet to be observed transaction signal. It is the contention of the authors that buy orders are effected at the ask price and sell orders at the bid price. In fixing these prices, the market maker is compelled to include the cost associated with the trade  $\phi$  into the quoted prices. As a result of this inference, the transaction signal is already incorporated in the trade price at time  $t$ . Now, employing the two equations (2.1) and (2.2), one can infer that:

$$p_t = \mu_{t-1} + \theta(x_t - E[x_t|x_{t-1}])\phi x_t + \varepsilon_t + \xi_t \quad (2.3)$$

Equation (2.3) can then be estimated by characterising the temporal functioning of the order flow. Madhavan et al. (1997) assume a general Markov chain for the trade initiation variable.  $\gamma$  denotes the probability distribution that a trade executed at a bid price succeeds a trade executed at a ask price and vice versa. This can be expressed as  $\gamma = \Pr [x_t = x_{t-1} | x_{t-1} \neq 0]$ . For ease of execution, block traders usually split their orders into smaller bits. This translates into the assumption that orders are more likely to be sustained following expression of interest rather than reversal of orders. Hence,  $\gamma > 1/2$ . Other factors related to exchange trading mechanism etc can also be responsible for this practice.

The first-order autocorrelation of the transaction initiation variable is next denoted by  $\rho$ , this can be expressed as  $\rho = \frac{E[x_t x_{t-1}]}{V[x_{t-1}]}$ . It can then be proven that  $\rho = 2\gamma - (1 - \lambda)$ , such that autocorrelation of order flow component,  $\rho$  is an expanding function of  $\gamma$  and  $\lambda$ . When the likelihood of trading within the quotes ( $\lambda$ ) is 0 and  $\gamma = 1/2$  (i.e.  $\gamma$  is independent), the order flow is uncorrelated ( $\rho = 0$ ).

Madhavan et al. (1997) gives a transformation of equation (2.3) into a form in which it can be used in decomposing spread components. They substitute out the belief lag one period (the prior belief),  $\mu_{t-1}$ . Contingent on  $\mu_{t-1} = p_{t-1} - \phi x_t - \xi_{t-1}$  and  $E[x_t | x_{t-1}] = \rho x_{t-1}$ , equation (2.3) can therefore be written as:

$$p_t - p_{t-1} = (\phi + \theta)x_t - (\phi + \rho\theta)x_{t-1} + \varepsilon_t + \xi_t - \xi_{t-1} \quad (2.4)$$

When friction exists in the market, in the application of equation (2.4), the trading price shifts will evidence the order flow due to market inefficiencies and public information impacts. When there are no frictions in the market however, equation (2.4) becomes representative of an efficient market following the classical random walk.

#### *Estimating Madhavan et al.'s (1997) Spread Decomposition Model*

Based on the Madhavan et al. (1997) model, one can conclude that the functioning of the market in terms of trade prices and quotes are subject to four parameters: the asymmetry information parameter,  $\theta$ ; the cost of liquidity provision by the market maker parameter,  $\phi$ ; the probability of a trade occurring within the quotes parameter,  $\lambda$  and the autocorrelation of the order flow parameter,  $\rho$ .

According to Madhavan et al. (1997), the parameter vector  $\beta = (\theta, \lambda, \gamma, \rho)$  can be estimated using the GMM estimator standardised by Hansen (1982). The GMM is a more suitable option than other estimation methods such as maximum likelihood as robust hypotheses for the stochastic flow generating the data is not needed. It also permits adaptation for structures of autocorrelation and conditional heteroscedasticity (see Huang and Stoll, 1994; Huang and Stoll, 1997; Madhavan et al., 1997). The model has five moment conditions specifically identifying the parameter vector  $\beta$  and the drift term (constant)  $\alpha$ :

$$E \begin{pmatrix} x_t x_{t-1} - x_t^2 \rho \\ |x_t| - (1 - \lambda) \\ \mu_t - \alpha \\ (\mu_t - \alpha)x_t \\ (\mu_t - \alpha)x_{t-1} \end{pmatrix} = 0 \quad (2.5)$$



The first condition specifies the first order autocorrelation in quotes; the second is a definition of the probability of a trade occurring at mid-quote, the third moment condition is a definition of the expectation of the drift term as the mean asset pricing error. The final two moment conditions follow the normal form in OLS estimation. Under GMM estimation, the parameter vector is decided to ensure the sampling of the population moments is executed such that the sample best estimates the population based on a specific weighting matrix, the choice of which is irrelevant. The asymptotic normality and consistency of the GMM parameter vector estimates are validated by Hansen (1982).

#### **2.4.3.2. Huang and Stoll (1997) Three-Way Spread Decomposition Model Based on Portfolio Trading Pressure**

This approach employs the fact that quote shifts due to inventory costs do not arise from inventory alterations in just one instrument (i.e. the instrument of interest) but from other instruments held in a portfolio. This is a portfolio approach to decomposing the spread, it is based on the assumption that adverse information relates to instruments on individual basis, but inventory impacts are portfolio wide. In employing this approach, I assume that ‘liquidity suppliers’ execute ECX trades in the sample. This is not to be interpreted as meaning trades by market makers, but as trades executed by participants whose actions provides availability of required orders in the market. These orders help enhance market liquidity and since they are mostly limit orders, also impose the pricing restrictions akin to a market maker. It is a simple view of the market that has been adopted by some microstructure studies (see for example Madhavan et al., 1997). Indeed Huang and Stoll (1997) propose a refinement of their approach through the nomination of specific portfolios other than a market maker’s, for example, a specialist portfolio or traders using limit orders.

Consider a liquidity supplier purchasing instrument  $x$  at the bid quote, the trade will lower the bid and offer prices of the instrument as well as other correlated instruments, and the sale in the correlated instruments, hedges his position in instrument  $x$ . In reverse, holding the assumption that the other instruments are constrained by trading pressure, the liquidity supplier can choose not to induce lowering of the quoted prices for instrument  $x$  if his aim is to hedge his buying of other instruments thereby spurring sales in instrument  $x$ . This approach recognises there is a probability that instrument  $x$ ’s quotes are driven by more than is given by the inventory impacts and information components of only instrument  $x$ .

Specifically, trading pressure on account of other instruments should result in alterations in quotes of instrument  $x$  due to the efforts of liquidity suppliers to retain the balance of their portfolios.

### *A Simple Model*

Assuming no transaction costs,  $V_t$  the hidden core value of an instrument is established just before the bid and offer quotes are published at time  $t$ . Quote mid-price denoted as  $M_t$  will only be computed as the quotes are released. Let trade price at time  $t$  be  $P_t$  and  $Q_t$ , the purchase/sale indicator variable for the trade price,  $P_t$ .  $Q_t$  equals +1 if the trade is initiated by the buyer and also executes at a price higher than the mid-price, -1 if the trade is seller initiated and also executes below the mid-price and finally takes the value of 0 if the trade executes at the mid-price. The hidden  $V_t$  is modelled as below:

$$V_t = V_{t-1} + \alpha \frac{s}{2} Q_{t-1} + \varepsilon_t, \quad (2.6)$$

$S$  corresponds to the constant spread,  $\alpha$  is the percentage of half-spread due to adverse selection costs, while  $\varepsilon_t$  represents the serially uncorrelated public information shock. The equation (2.6) decomposes transaction costs,  $V_t$  into two elements. The first is the private information element uncovered from the previous trade,  $\alpha \frac{s}{2} Q_{t-1}$  (see Copeland and Galai, 1983; Glosten and Milgrom, 1985). And second, public information element encapsulated by  $\varepsilon_t$ . Although, transaction cost  $V_t$  is purely theoretical, the midpoint,  $M_t$  of the spread is observable. Suppliers of liquidity aim to achieve inventory equilibrium therefore effect equilibrium-inducing transactions by modifying quotes (hence mid-price). The adjustments are carried out in relation to the core value instruments as is informed by inventory levels (see for example Ho and Stoll, 1981; Stoll, 1978). Suppose that previous transactions are of a regular size of one, the midpoint (mid-price) in relation to the core instrument value then corresponds to:

$$M_t = V_t + \beta \frac{s}{2} \sum_{i=1}^{t-1} Q_i, \quad (2.7)$$

$\beta$  corresponds to the magnitude of the half-spread measure due to inventory costs, where  $\sum_{i=1}^{t-1} Q_i$  is the aggregate inventory from when the market opens to time  $t-1$ , and  $Q_t$  is the inceptive inventory for that trading day. If there is no inventory holding costs, the ratio of  $V_t$  to  $M_t$  will be one. Equation (2.7) holds for bid, offer and mid-prices since it is already assumed that the spread is constant.

First differencing of equations (2.7) and (2.6) suggests that quotes are generally modified to show inventory costs and information exposed by the last transaction. Specifically, we have:

$$\Delta M_t = (\alpha + \beta) \frac{s}{2} Q_{t-1} + \varepsilon_t \quad (2.8)$$

with  $\Delta$  as the first difference operator.

Equation (2.9) cites the assumption of a constant spread:

$$P_t = M_t + \frac{s}{2} Q_t + \eta_t \quad (2.9)$$

Where  $\eta_t$  is the error term and it encapsulates the deviation of the observable half-spread,  $P_t - M_t$  from the constant half-spread,  $\frac{s}{2}$ , with the inclusion of price discreteness induced rounding errors. The estimable traded spread,  $S$  is distinguishable from the observable spread,  $S_t$  because it is representative of trades outside the midpoint but within spread. Transactions within the quoted spread and executed above the midpoint are regarded as ask transactions, and trades within the spread and executed below the midpoint are the bid trades. When  $S$  is estimated, it will be larger than the effective spread, which is the absolute value of transaction price minus the prevailing midpoint,  $|P_t - M_t|$ . This is due to the exclusion of midpoint trades ( $Q_t = 0$ ) from the estimation. In contradiction to this, the unobserved estimated spread  $S$ , obtained from serial covariance of transaction prices (see Roll, 1984) are swayed by volume of midpoint transactions. Harris (1990) however suggests that the Roll (1984) spread estimator may be significantly biased.

When equations (2.8) and (2.9) are integrated, the basic regression model (2.10) is produced:

$$\Delta P_t = \frac{s}{2}(Q_t - Q_{t-1}) + \lambda \frac{s}{2} Q_{t-1} + e_t, \quad (2.10)$$

Whereby  $\lambda = \alpha + \beta$  and  $e_t = \varepsilon_t + \Delta\eta_t$ . The regression model (2.10) is a nonlinear indicator variable model with within-equation restrictions. The requirement for estimation is the indication of if the transactions at  $t$  and  $t-1$  execute at any of ask, bid or mid prices. The model estimation yields the traded spread,  $S$ , and the aggregate modification of quotes to transactions,  $\lambda(S/2)$ . The estimation equation (2.10) does not yield independent estimates of adverse selection component,  $\alpha$  and the inventory holding component,  $\beta$ . Nevertheless, proportion of the half-spread which is not attributable to adverse information or inventory holding can be estimated as  $1 - \lambda$ . This is the order processing costs estimate.

#### *Extension of Model based on Portfolio Trading Pressure*

Equation (2.10) does not consider the effects of normal trading pressure because the inventory modification earlier modelled in Equation (2.7) is based on individual instrument inventory held. The next step is therefore to differentiate transaction signs of the distinct instruments. If  $k$  corresponds to instrument  $k$ , Equation (2.7) then becomes:

$$M_{k,t} = V_{k,t} + \beta_k \frac{S_k}{2} \sum_{t=1}^{t-1} Q_{A,t} \quad (2.11)$$

where  $Q_{A,t}$  corresponds to the aggregate buy-sell indicator variable defined as follows:

$$\begin{aligned} Q_{A,t-1} &= 1 \text{ for } \sum_{k=1}^n Q_{k,t-1} > 0 \\ Q_{A,t-1} &= -1 \text{ for } \sum_{k=1}^n Q_{k,t-1} < 0, \\ Q_{A,t-1} &= 0 \text{ for } \sum_{k=1}^n Q_{k,t-1} = 0 \end{aligned} \quad (2.12)$$

where  $n$  corresponds to the number of instruments that suppliers of liquidity review to determine the mood of the market. Equation (2.11) can be written as

$$\Delta P_{k,t} = \frac{S_k}{2} \Delta Q_{k,t} + \alpha_k \frac{S_k}{2} Q_{k,t-1} + \beta_k \frac{S_k}{2} Q_{A,t-1} + e_{k,t} \quad (2.13)$$

The model (2.13) remains an indicator variable model, in the absence of portfolio trading effects/frictions; it reverts to equation (2.10). A key distinction however is that with Equation (5.14) all spread components of the bid-ask spreads can be estimated individually.

Model (2.13) can be estimated using GMM procedure with appropriate adjustments to the orthogonality conditions. The GMM levies relatively weak distributional requirements unlike maximum likelihood<sup>9</sup> (see Madhavan et al., 1997; Huang and Stoll, 1997). Also it is necessary to align the trading times across all instruments involved in the estimation. Further down in this section, I provide an analysis of the procedure adopted in order to ensure this alignment (see also Huang and Stoll, 1997).

Further, an econometric improvement controlling for correlations across instruments can be made to equation (2.13). As all instruments react to information in the public domain, the public information effects element in  $e_{k,t}$  may be contemporaneously correlated across the instruments. A panel estimation of equation (2.13) may be more efficient according to the authors; however, the panel estimation forces a reduction in number of observations and moreover, the inferences made with the time series estimations are essentially the same with the panel estimation inferences.

Since this approach basically models market participants as adopting a portfolio view when executing inventory modification of stocks, it is related also to the Ho and Stoll (1983) model that shows the connection between quote shifts in a stock and shifts in others. The authors prove that the quote shifts in stock  $a$  which is in reaction to a transaction in stock  $b$  is contingent on  $cov(R_a, R_b)/\sigma^2(R_b)$ . The model has been established by several other studies (see Van Ness et al., 2001; Heflin and Shaw, 2000). Van Ness et al. (2001) suggest that the Huang and Stoll (1997) model is superior to other commonly used models in measuring adverse selection information costs. However, the “superiority” of the model has its costs. Some authors have reported the possibility of obtaining implausible estimates from the model estimation when using the probability of trade reversal approach in place of trading pressure

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<sup>9</sup> The model can be estimated using ML and LS as long as the distributional assumptions are either met or can be accounted for with estimation procedures such as the application of Newey and West (1987) HAC. In this thesis, I opt for LS as is the case with Heflin and Shaw (2000).

approach. For example Clarke and Shastri (2000) report this problem analysing a sample of 320 NYSE firms, indeed Van Ness et al. (2001) also report similar issues. It seems that there is a correlation between low probability of trade reversal and the implausible estimates. For this chapter, I report only the trade aggregator estimation and there is no evidence of this problem especially since the estimates are comparable to those of Benz and Klar (2008) estimated using the Madhavan et al. (1997) model.

Equation 2.13 can be expressed simply as:

$$\Delta P_{k,t} = \beta_{1,k}Q_{k,t} + \beta_{2,k}Q_{k,t-1} + \beta_{3,k}Q_{A,t-1} + e_t, \quad (2.14)$$

where  $\Delta P_{k,t}$  is the change in price from the previous retained trade,  $Q_{k,t}$  is equal to 1 (-1) when the transaction at period  $t$  for contract  $k$  was a liquidity provider sell (buy) and  $Q_{A,t-1}$  is the aggregate buy-sell indicator variable used in encapsulating portfolio trading pressure on market participants inventory levels. It is measured as in (2.12). The adverse selection spread component and the half spread are thus computed by estimating equation (2.14) using the ordinary least squares as was adopted by Heflin and Shaw (2000).

This study follows Huang and Stoll (1997) in employing only the last trade at every five-minute interval in formulating the variables in equation (2.14).<sup>10</sup> Huang and Stoll (1997) observe that big trades are sometimes broken up and registered as smaller trades (see also Barclay and Warner, 1993; Chakravarty, 2001). To counter the problems that may arise from this, they employ a “bunching” technique whereby trades occurring within five minute intervals of each other, executed at the same price and with same quotes are bunched together and regarded as one trade. They however point out that using one trade every five minutes as adopted in this study greatly reduces any problem that may arise from large trades being broken up and reported as smaller trades. Heflin and Shaw (2000) adopt this approach as well. Moreover the results obtained by Huang and Stoll (1997) from the bunching technique suggest that the method increases the adverse selection component estimates. As devised in equation (2.14), the  $\beta_{1,k}$  estimate is one-half the estimated effective spread and, the adverse

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<sup>10</sup>For the RTH, equation (2.14) is estimated using the trade classification provided by ECX in the dataset and also by employing the tick rule (Lee and Ready, 1991), estimates obtained from both methods are quantitatively similar. Results based on the tick rule are reported for both RTH and AMC periods.

selection component is equivalent to  $2(\beta_{2,k} + \beta_{1,k})$ . The Wilcoxon-Mann-Whitney test is used for obtaining statistical inference on the level of differences between the RTH intervals and the AMC period.

In Panel A of Table 2.2 the estimated adverse selection costs components of the effective spread for each contract and time interval are reported. The combined contracts' averages for the intervals are also reported. The results largely support the hypothesis on reducing information asymmetry over the course of RTH. In the RTH, information asymmetry is highest in earlier intervals. Overall, it is highest between 7:00hrs and 11:00hrs than at any interval during the rest of RTH. As expected there is a high level of information asymmetry after the close to support the suggestion that those who trade in this market do so based on private information. Following the explanation in section 2.4.2, the uniqueness of this market lends credence to the conjecture that this is the case. The results are also consistent with earlier studies finding higher levels of informed trading in the AMC period than during the RTH (see Barclay and Hendershott, 2003; He et al., 2009; Jiang et al., 2010). The average adverse selection spread component for all contracts during the AMC is almost 12 times the value for the normal trading day (07:00-17:00). This implies that participants are significantly more likely to trade with private information in the AMC market than during the normal trading day. Although the investigations on information asymmetry is conducted in a relatively less active and quite unusual market, the adverse selection and half effective spread estimates in the RTH period are comparable to estimates from most previous studies (see as examples Glosten and Harris, 1988; George et al., 1991; Lin et al., 1995; Huang and Stoll, 1997; Heflin and Shaw, 2000; Madhavan et al., 1997).

Panel B presents the effective half-spread estimates. The results confirm the hypothesis that spreads are wider in the AMC period than in the RTH. The results in the RTH are also comparable to the results obtained by Benz and Klar (2008) using the Madhavan et al. (1997) model to estimate half spread in the ECX during Phase I of the EU-ETS. Spreads are generally higher during the first two hours of trading than at any other period during the RTH. All the half-effective spread estimates are statistically significant.

**Table 2.2. Information Asymmetry And Half-Spread By Time Interval**

The table shows adverse selection costs components in Panel A and one-half effective spreads in Panel B for the four highest volume December maturity contracts on the European Climate Exchange (ECX) platform. Both the adverse selection costs components and the one-half spread components are estimated using the following contract specific model (Huang and Stoll, 1997) using LS with Newey and West (1987) HAC:

$$\Delta P_{k,t} = \beta_{1,k} Q_{k,t} + \beta_{2,k} Q_{k,t-1} + \beta_{3,k} Q_{A,t-1} + e_t$$

where  $\Delta P_{k,t}$  is the change in price from the previous retained trade,  $Q_{k,t}$  is equal to 1 (-1) when the transaction at period  $t$  for contract  $c$  was a sell (buy) and  $Q_{A,t-1}$  is the aggregate buy-sell indicator variable used in encapsulating portfolio trading pressure on market participants inventory levels, it equals 1(-1, 0) when the sum of  $Q_{k,t-1}$  across all four contracts is positive (negative, zero). Adverse selection costs component for each interval in Panel A is given as:

$$2(\beta_{2,k} + \beta_{1,k})$$

One-half effective spread for each interval in Panel B is given as  $\beta_{2,k}$ . Pairwise Wilcoxon-Mann-Whitney U tests are used to compute p-values for the differences between each of the different contract-dependent normal trading day intervals and the AMC period. In both panels, <sup>#</sup> denotes the normal trading day intervals during which the contract estimates are significantly different from the AMC. In Panel B, \* denotes statistical significance of the spread estimates at 1% level. The data covers the trading period February 2009 through November 2009. The normal trading day period runs between 7:00hrs and 16:59:59hrs London time and the AMC runs between 17:00hrs and 18:00hrs London time.

**Panel A: Adverse Selection Costs**

Contracts	Time Periods						
	Normal Trading Day					AMC	
	07:00- 09:00	09:00- 11:00	11:00- 13:00	13:00- 15:00	15:00- 17:00	07:00- 17:00	17:00- 18:00
Dec-2009	0.016	0.036	0.012	0.001	0.002	0.014	0.411
Dec-2010	0.044	0.024	0.024	0.032	0.000	0.022	0.403
Dec-2011	0.049	0.083	0.047	0.028	0.032	0.053	0.511
Dec-2012	0.084	0.062	0.058	0.080	0.036	0.063	0.489
Overall	0.048 <sup>#</sup>	0.051 <sup>#</sup>	0.035 <sup>#</sup>	0.035 <sup>#</sup>	0.017 <sup>#</sup>	0.038 <sup>#</sup>	0.453

**Panel B: One Half Spread Estimates**

Contracts	Time periods						
	Normal Trading Day					AMC	
	7:00- 9:00	9:00- 11:00	11:00- 13:00	13:00- 15:00	15:00- 17:00	07:00- 17:00	17:00- 18:00
Dec-2009	0.026*	0.023*	0.025*	0.017*	0.017*	0.021*	0.235*



Dec-2010	0.045*	0.025*	0.032*	0.020*	0.018*	0.027*	0.239 *
Dec-2011	0.050*	0.057*	0.042*	0.038*	0.025*	0.041*	0.324 *
Dec-2012	0.072*	0.051*	0.083*	0.057*	0.038*	0.056*	0.348 *
Overall	0.048 <sup>#</sup>	0.039 <sup>#</sup>	0.045 <sup>#</sup>	0.033 <sup>#</sup>	0.024 <sup>#</sup>	0.036 <sup>#</sup>	0.286

#### 2.4.4. Price Discovery; Information absorption on the ECX

It is established in literature that price discovery is a function of trading activity; these two are connected (see Jiang et al., 2012; Pascual et al., 2004; Kim et al., 1999; French and Roll, 1986). In section 2.4.3 it is demonstrated that information asymmetry is higher during AMC session than during the normal trading day. One can also see that spreads grow larger in the AMC period as well. This implies that there should be a higher proportion of price discovery per hour taking place during the AMC. Results obtained during the open-close period by Barclay and Hendershott (2003) suggest that the least trading instruments contribute the higher proportion of price discovery during the regular trading hours. Table 2.1 shows that the December-2011 and December-2012 contracts are the least trading, therefore the expectation is that they will contribute the highest ratio of price discovery during the normal trading period. The study now turns to examining how the level of trading activity influences the incorporation of information during the two periods (and the various intervals).

##### 2.4.4.1. Weighted Price Contribution

The weighted price contribution (WPC) measure already established by previous studies (see Barclay and Warner, 1993; Barclay et al., 1990; Cao et al., 2000; Barclay and Hendershott, 2004; van Bommel, 2011)<sup>11</sup> is adopted as measure of price discovery. The WPC of the EUA futures contracts during five intervals of the RTH and the one-hour AMC period are calculated. Also derived are estimates for the total price discovery for the RTH period (07:00-17:00hrs London local time). The terminal period for the RTH is the last trade at or before

<sup>11</sup> van Bommel (2011) analyse three estimators of price discovery and identified the WPC as consistent, also it is the only unbiased and asymptotically normal measure for price discovery if the price process follows a driftless martingale.

17:00:00hrs and the AMC period as the first trade after 17:00:00hrs. The WPC measure used estimates the proportion of the 24-hour (close-close) EUA contract price return that takes place at that period.

For each contract, this study defines the WPC for each 24 hour period and each period  $k$  as:

$$WPC_{k,c} = \left( \frac{|ret_c|}{\sum_{c=1}^C |ret_c|} \right) \times \left( \frac{ret_{k,c}}{ret_c} \right) \quad (2.15)$$

Where  $ret_c$  is the close-to-close return for contract  $c$  and  $ret_{k,c}$  is the log-return for period  $k$  and for EUA contract  $c$ . The intuition behind the WPC is that  $\frac{ret_{k,c}}{ret_c}$  is measure of relative proportion of the day's return provided by contract  $c$  and  $\frac{|ret_c|}{\sum_{c=1}^C |ret_c|}$ , the standardised absolute value of  $ret_c$ , is the weighing factor for each contract. It ensures that values with smaller  $|ret_c|$  are given small weight. Thus, the WPC is computed for each contract and average across days to obtain the WPC for each time period for each contract. The WPC across all the contracts is also reported. This is defined as:

$$WPC_k = \sum_{c=1}^C \left( \frac{|ret_c|}{\sum_{c=1}^C |ret_c|} \right) \times \left( \frac{ret_{k,c}}{ret_c} \right) \quad (2.16)$$

Normally the WPC is computed instrument by instrument and then averaged out across the instruments (see Cao et al., 2000). When this is the case however, instrument correlations generated by the common constituent in the returns makes statistical inferences a complex affair using the mean WPC. Since the WPC is reported individually for each contract one need not be concerned about this; therefore the standard t-statistic is applied to test the null that the daily WPC values (per period and for each contract) are not significantly different from zero. The Wilcoxon-Mann-Whitney test is also used for obtaining statistical inference on the level of differences between the RTH intervals and the AMC period.

Table 2.3 shows the WPC estimates for the 24-hour (close-to-close). The results show that the most liquid contract (Dec-09) contributes the least to price discovery over the entire

trading periods. Recalling the results from Table 2.1, this suggests that price discovery contribution is a function of trading activity levels. Based on this, it is anticipated that the Dec-2011 and Dec-2012 contracts will be the highest contributors to price discovery. Results in Table 2.3 support this expectation: the Dec-2012 and the Dec-2011 contracts are the two highest contributors to price discovery over all the trading periods (55% and 31% respectively). Together they account for 86% of total price discovery over the entire periods. Their contributions over the combined RTH period (07:00-17:00hrs) and the AMC period are statistically significant. This is to be expected because EU-ETS trading, as explained in section 2.4.2, is dependent on information relating to emission levels, political and regulatory shifts on environmental legislations and global treaties. In this context, it is likely that the primary motivation for taking a position on a contract with maturity about three years away is possession of information that this is a good move either for hedging or otherwise. It is similar to taking a position on more traditional commodity contracts.

Overall, most of the price discovery takes place during the RTH-over a 10-hour period. However more than a quarter of the price discovery occurs during the space of just one hour (17:00hrs-18:00hrs) in the AMC trading period, despite reduced number of executed trades. Another observation is that more than 21% of the total close-close price discovery occurs in the first two hours (07:00hrs-09:00hrs) of the RTH. This is interesting considering the fact that only about 10.5% volume of trades for all periods occur during this period (Figure 2.1). Moreover, more than 81% of these trades are in the Dec-2009 contract that contributes nothing to price discovery during the period. The consistency of this result with the results in Table 2.2 showing information asymmetry (for RTH) in general decline from the high levels of the morning trading period is important. The hypothesis that there is an accumulation of information during the non-trading 12.75-hour period therefore holds. If this is the case, it is expected that individual trades in the opening period will contribute more to price discovery than the trades at any other period during RTH. The expectation here does not include the AMC because, although the period enjoys the highest volume per minute of trade, the aggregate number of trades is vastly inferior to those in the RTH. This implies that the trades in the AMC are potentially as informative as the opening period. This hypothesis is tested in section 2.4.4.2. It is also observed that the lowest average WPC during the periods is recorded during the 11:00-13:00hrs range. In Figure 2.1, this period has the highest level of volatility relative to trading volume. The high return volatility and low WPC estimates raise

the suggestion of noisiness during the RTH. In the next section, this matter will be examined more closely.

**Table 2.3. Weighted Price Contribution by Time Intervals**

The table shows weighed price contribution (WPC) of six normal trading day intervals and the After Market Closes (AMC) period to the close-to-close return for the four highest volume December maturity contracts on the European Climate Exchange (ECX) platform. For each contract and interval  $k$  the weighed price contribution is computed for each day and then averaged across days:

$$WPC_{k,c} = \left( \frac{|ret_c|}{\sum_{c=1}^C |ret_c|} \right) \times \left( \frac{ret_{k,c}}{ret_c} \right)$$

where  $ret_{k,c}$  is the log-return for interval  $k$  and for EUA contract  $c$ .  $ret_c$  is the close-to-close return for contract  $c$ . The trading days when close-to-close returns equal 0 are eliminated. The final column shows the fraction of days with close-to-close return equal to 0. The overall estimate in the final row is the sum of WPC for all contracts in that time interval. Wilcoxon-Mann-Whitney (tie-adjusted) tests are used to determine whether contract-dependent values for normal trading day intervals are significantly different from the AMC period. # denotes the contract-dependent normal trading day interval during which the contract WPC is significantly different from that of the AMC. \* indicates the WPC values significantly different from 0 at the 5% level. The data covers the trading period February 2009 through November 2009. The normal trading day period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.

Time Periods								
Contracts	Normal Trading Day					AMC	Days	
	07:00-09:00	09:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	07:00-17:00	17:00-18:00	with zero price change
Dec-2009	-0.006 <sup>#</sup>	-0.006	-0.02	-0.034	0.038	-0.028	0.003	0.019
Dec-2010	0.083 <sup>*#</sup>	0.038 <sup>#</sup>	-0.027	0.04	0.059 <sup>*#</sup>	0.193 <sup>*#</sup>	-0.028	0.019
Dec-2011	0.051	0.015 <sup>#</sup>	0.037 <sup>#</sup>	0.042	0.084 <sup>*</sup>	0.229 <sup>*</sup>	0.081 <sup>*</sup>	0.024
Dec-2012	0.084 <sup>*</sup>	0.072 <sup>*</sup>	0.029 <sup>#</sup>	0.026 <sup>#</sup>	0.109 <sup>*</sup>	0.32 <sup>*</sup>	0.23 <sup>*</sup>	0.019
Overall	0.212 <sup>*</sup>	0.119	0.019	0.074	0.29 <sup>*#</sup>	0.714 <sup>*#</sup>	0.286 <sup>*</sup>	0.019

#### 2.4.4.2. Weighted Price Contribution per Trade

The high WPC estimate recorded for the first two hours (07:00-09:00hrs) of the RTH coupled with its low level of trading in comparison with the other periods provide the basis to expect high information content per trade during the period. The adverse selection component is also

highest during this period in the RTH. The study therefore proceeds by examining the information content per trade by using the weighted price contribution per trade (WPCT) measure. The WPC per trading period (interval) is divided by the weighted ratio of trades executed during that period (interval). If for each day,  $t_{k,c}$  is the number of executed trades in time period  $k$  for contract  $c$ , and  $t_c$  is the total sum of  $t_{k,c}$  for all the periods, then  $WPCT_{k,c}$  is defined as

$$WPCT_{k,c} = \frac{\left( \frac{|r_{k,c}|}{\sum_{c=1}^C |r_{k,c}|} \right) \times \left( \frac{r_{k,c}}{r_c} \right)}{\left( \frac{|r_c|}{\sum_{c=1}^C |r_c|} \right) \times \left( \frac{t_{k,c}}{t_c} \right)} \quad (2.17)$$

As a consequence of the measure being equivalent to a ratio of the aggregate price shift occurring in a period scaled by the ratio of trades in that same period, the WPCT should be about one assuming all trades carry similar levels of information to the market. For statistical inference, the standard t-statistic is used to test the null that the daily WPCT values (per period and for each contract) are not significantly different from zero. The Wilcoxon-Mann-Whitney test is also used to obtain statistical inference on differences between RTH intervals and the AMC period.

The close-to-close WPCT is reported in Table 2.4. The results show that for three of the contracts, the trades in the opening period hold higher levels of information than at any time during the normal trading periods. Some of the estimates for the RTH are noisy as they are not statistically significant. Consistent with Panel A of Table 2.2 and Table 2.3, on per contract basis, the contract with the farthest maturity, the December-2012 contract holds the highest level of information per trade. It is also observed that as in Table 2.3, individual trades in the period 15:00hrs-17:00hrs are very informative and are largely statistically significant across all contracts. The informed trading effect of the increasing EFP/EFS trades at this period is more evident as the volume of liquidity seeking trades start to taper off. This implies that the level of price discovery reported for this period will have a level of efficiency comparable to that of the AMC period. This is examined in the next section (2.4.5). The results in this section (Tables 2.3 and 2.4) thus support that the AMC as well as the opening two hours are very important to the price discovery process.

**Table 2.4. Weighted Price Contribution Per Trade by Time Intervals**

The table shows weighted price contribution per trade (WPCT) of six Regular Trading Hours normal trading day intervals and the After Market Closes (AMC) period to the close-to-close return for the four highest volume December maturity contracts on the European Climate Exchange (ECX) platform. For each contract and interval  $k$  the weighted price contribution per trade is computed for each day and then averaged across days:

$$WPCT_{k,c} = \frac{\left(\frac{|r_{ret}|}{\sum_{c=1}^c |r_{ret}|}\right) \times \left(\frac{r_{k,c}}{r_{ret}}\right)}{\left(\frac{|r_{ret}|}{\sum_{c=1}^c |r_{ret}|}\right) \times \left(\frac{k}{c}\right)},$$

$t_{k,c}$  is the number of executed trades in time interval  $k$  for contract  $c$ , and  $t_c$  is the total sum of  $t_{k,c}$  for all the intervals. The trading days when close-to-close returns equal 0 are eliminated. The final column shows the fraction of days with close-to-close return equal to 0. Wilcoxon-Mann-Whitney (tie-adjusted) tests are used to determine whether contract-dependent values for normal trading day intervals are significantly different from the AMC period. # denotes the contract-dependent normal trading day interval during which the contract WPCT is significantly different from that of the AMC. \* indicates the WPCT values significantly different from 0 at the 5% level. The data covers the trading period February 2009 through November 2009. The normal trading day period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.

Contracts	Time Periods							
	Normal Trading Day						AMC	Days with zero price change
	07:00-09:00	09:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	07:00-17:00	17:00-18:00	
Dec-2009	-0.12 <sup>#</sup>	-0.15	-0.57	-0.68	0.63	-0.12	0.31	0.019
Dec-2010	2.54 <sup>*#</sup>	0.76 <sup>#</sup>	-0.72	0.86 <sup>#</sup>	0.78 <sup>*#</sup>	0.80 <sup>*#</sup>	-2.90	0.019
Dec-2011	1.96 <sup>*</sup>	0.33	1.13 <sup>#</sup>	0.83 <sup>#</sup>	0.92 <sup>*</sup>	0.93 <sup>*</sup>	11.54 <sup>*</sup>	0.024
Dec-2012	2.78 <sup>*</sup>	1.75 <sup>*</sup>	1.04 <sup>#</sup>	0.63 <sup>#</sup>	1.10 <sup>*</sup>	1.34 <sup>*</sup>	25.53 <sup>*</sup>	0.019
Overall	1.79 <sup>#</sup>	0.67	0.22	0.41	0.86 <sup>*#</sup>	0.74 <sup>*#</sup>	8.63 <sup>*</sup>	0.019

### 2.4.5. Efficiency of Price Discovery: Analysis by Period

In markets with relatively slim trading volumes like the EU-ETS platforms, big liquidity induced trades usually associated with short-term price effects that are afterward reverted. Although the highest proportion of large contract trades is in the AMC, results shown so far suggest there are more liquidity driven trades in the RTH than in the AMC. Based on this, it is anticipated that the RTH trades will be generally noisier than the AMC trades because of price reversals.

However, since large spreads as shown in Panel B of Table 2.2 for the AMC period are typically instrumental to price reversals, there is also the suspicion that there may be an

appreciable level of noisy trades in the AMC. Hence the hypothesis here is for lower signal: noise ratio for the RTH than the AMC. Based on foregoing analysis, it is also expected that the Dec-2011 and Dec-2012 (the most illiquid instruments in the sample) will possess generally low signal: noise ratio (noisy) across all periods. In section 2.4.4.1, the observation that high volatility levels and low WPC estimates reported for the 11:00-13:00hrs period may indicate the presence of noisy trades is made; hence the lowest signal: noise ratio estimates in the RTH is expected for this period. Price efficiency is measured using the so-called unbiasedness regressions, this involves estimating the noisiness of contract prices for different intervals (see Biais et al., 1999).

For each contract and each day equation (3.6) is estimated separately for each time period (60 minutes each for the RTH and 10 minutes each for the AMC), where  $ret_{cc}$  is the close to close return and  $ret_{ck}$  is the return from the close to the end time of period  $k$ :

(2.18)

Barclay and Hendershott (2003) argue that the slope coefficient  $\beta$  is a measure of signal: noise ratio. Reviewing the regression analysis problem of standard errors-in-variables, assuming contracts returns are accurately computed and they are not correlated, the slope coefficient will equal one. Then take the assumption that the actual return is not observed and also that the observable return is actually equivalent to the real return plus the noise. Noise in this sense refers to microstructure impacts such as spread components or reversible price effects. If one imagines that  $ret_{cc} = RET_{cc} + v$  and  $ret_{ck} = RET_{ck} + u$ . Then consider  $RET_{cc}$  and  $RET_{ck}$  as the actual returns and  $u$  and  $v$  have zero mean and respective variances equivalent to  $u^2$  and  $v^2$ . An ordinary least squares estimation of Equation (3.4) will result in the estimated slope coefficient  $\beta^*$ , where

$$plim \beta^* = \beta \left( \frac{\sigma^2_{RET_{ck}}}{\sigma^2_{RET_{ck}} + \sigma^2} \right) \quad (2.19)$$

$\sigma^2_{RET_{ck}}$  is a measure of the total information observed from the previous close to the time period  $k$  and  $\sigma_u^2$  is the noise effect observed in prices at period  $k$ . The slope thus measures the ratio of information content (signal) to signal plus noise in prices at period  $k$ .

Specifically, a time series estimation of equation (3.6) for each contract and each time period is conducted. The slope coefficient estimates for each contract is obtained and the mean for all the contracts with respect to each of the time periods calculated. Following Biais et al. (1999), the confidence bands are calculated using the time series' standard errors of the mean of the slope coefficient estimates. As pointed out by Biais et al. (1999) time series estimation of instrument returns in the presence of learning is problematic as a result of learning induced non-stationarity. This is relevant to this analysis, especially since is based in part on learning in the after hours market. To ensure that this analysis does not suffer from the spurious regression problem, individual unit root tests of each time series variable used in the separate regressions is conducted. The test results suggest that the variables are stationary. In any case, the Newey and West (1987) heteroscedasticity and autocorrelation consistent covariance (HAC) matrix estimator, which is consistent in the presence of both heteroscedasticity and autocorrelation of unknown form, is applied. The results obtained from the HAC estimation are materially the same with the ones reported.

Figure 2.3 shows the graph of the signal: noise ratio with the confidence bands. In Table 2.5 are also two panels of the slope estimates for the RTH and AMC periods. Comparatively, the signal: noise ratio in the RTH is generally lower than the AMC as hypothesised. During the RTH, the signal: noise ratio ranged from about 0.37 to 0.78 and from 0.61 to 0.92 in the AMC, clearly indicating the RTH as being noisier than the AMC period. Ciccotello and Hatheway (2000) and Barclay and Hendershott (2003) find high signal: noise ratios that are sustained over the RTH for the Nasdaq-pre opening in 1996 and 2000 respectively. NASDAQ pre-open in 2000 daily averaged more than \$2million. Biais et al. (1999) instead find low signal: noise ratio for the Paris Bourse that has no official pre-open trading in 1991. Orders are allowed in the pre-open but no execution takes place in 1991 on the Paris Bourse, hence no volume is registered although the last 10 minutes before RTH begins is the most active period for order placement in the day. These facts and the results further underscore the generally held view that trading volumes form a vital component of efficient price discovery, especially in thin markets like the EU-ETS platforms. Indeed the highest trading periods of the day in the sample post the highest signal: noise ratios. This view is strengthened by the fact that low signal: noise ratio is more likely for the AMC than the RTH



because of propinquity to the close.<sup>12</sup> It is therefore proposed that higher trading volumes are associated with higher price efficiency and that this association holds more significance in thin markets.

Also the expectation of the 11:00-13:00hrs period is confirmed. The noisiest point of the day according to Figure 2.3 is at 13:00hrs as a result of the noisiness of price in the less liquid contracts (Dec-2012, Dec-2011 and Dec-2010). The Dec-2012 contract during this period is a lowly 0.054; underscoring the fact that majority of the trades in this contract are very noisy. The estimates suggest that the less liquid a contract is on the ECX platform, the higher the likelihood of its prices being noisy.

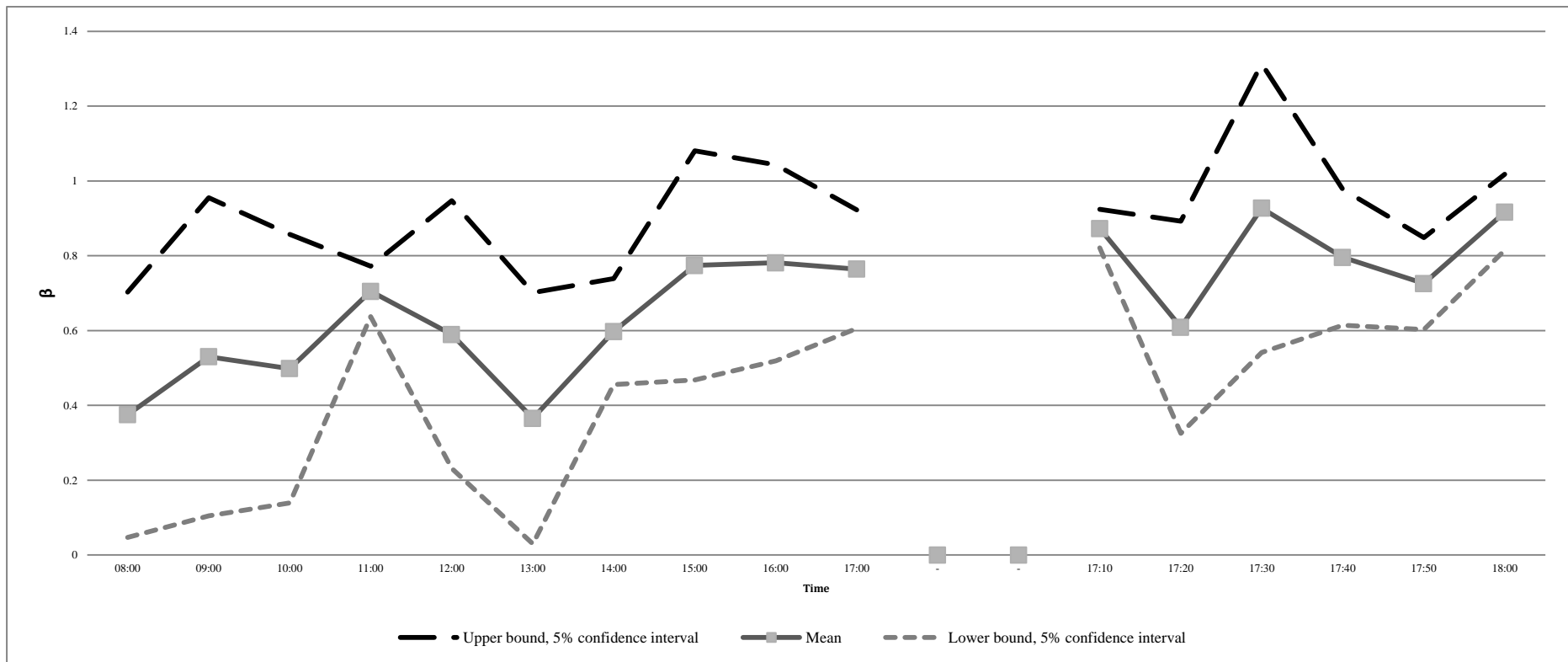
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<sup>12</sup> Alternate analysis run by Barclay and Hendershott (2003) on the NASDAQ however suggests this is unlikely; still it is a possibility that provides additional basis for the argument on the link between trading volume and price discovery efficiency.

**Figure 2.3. Unbiasedness Regressions by Intervals**

The figure shows the chart of signal:noise ratio over the entire trading periods of Regular Trading Hours (RTH) and After Market Closes (AMC) for the December maturity contracts (2009, 2010, 2011 and 2012) trading on the ECX platform. For each contract and each day, the following equation is estimated, using LS and Newey and West (1987) HAC, separately for each time period (60 minutes each for the RTH and 10 minutes for the AMC), where  $ret_{cc}$  is the close to close return and  $ret_{ck}$  is the return from the close to the end time of period  $k$ . Confidence bands are computed using the time series' standard errors of the slope coefficient estimates.

The data covers the trading period February 2009 through November 2009. The RTH period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.



The regression estimates for both the RTH and the AMC are obtained using the same close-close returns and are therefore correlated. This means the level of statistical difference between the AMC and RTH will be biased using the time series standard errors in Figure 2.3 and Table 2.5. In drawing statistical inference on the distinction between the slope coefficients, this level of contemporaneous correlation must be considered. This study follows Barclay and Hendershott's (2003) method of computing for every day, the difference between the RTH and AMC coefficients and employing the standard error of this time series to draw inferences on the difference between the two periods. The inference is based on the mean difference being significantly different from zero. The result shows that the signal: noise ratio was significantly higher in the AMC than the RTH.

**Table 2.5. Unbiasedness Regressions by intervals**

The table shows results of signal:noise ratio over the entire trading periods of Regular Trading Hours (RTH) (Panel A) and After Market Closes (AMC) (Panel B) for the December maturity contracts (2009, 2010, 2011 and 2012) trading on the ECX platform. For each contract and each day, the following equation is estimated, using LS and Newey and West (1987) HAC, separately for each time period (60 minutes each for the RTH and 10 minutes for the AMC), where  $ret_{cc}$  is the close to close return and  $ret_{ck}$  is the return from the close to the end time of period  $k$ .

\*\* denotes significance at 5% levels. The data covers the trading period February 2009 through November 2009. The RTH period runs between 7:00hrs and 16:59:59hrs London time; the AMC runs between 17:00hrs and 18:00hrs London time.

**Panel A: RTH**

Contracts		08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Dec-2009	Estimate	0.85	0.98	0.75	0.66	1.02	0.84	0.71	0.94	0.85	0.95
	Std Error	0.099	0.082	0.082	0.082	0.070	0.066	0.052	0.044	0.047	0.024
	t-statistic	8.54**	12.01**	9.08**	8.14**	14.56**	12.73**	13.51**	21.39**	18.05**	38.91**
	Adj. R <sup>2</sup>	0.26	0.41	0.28	0.24	0.50	0.44	0.47	0.69	0.61	0.88
Dec-2010	Estimate	0.37	0.82	0.83	0.80	0.76	0.36	0.72	0.86	0.91	0.86
	Std Error	0.086	0.080	0.061	0.068	0.068	0.067	0.059	0.053	0.031	0.034
	t-statistic	4.31**	10.18**	13.74**	11.79**	11.16**	5.35**	12.33**	16.39**	29.29**	25.02**
	Adj. R <sup>2</sup>	0.10	0.33	0.47	0.40	0.37	0.12	0.42	0.56	0.80	0.75
Dec-2011	Estimate	0.09	0.20	0.38	0.71	0.37	0.21	0.42	0.98	0.97	0.63
	Std Error	0.050	0.063	0.074	0.065	0.065	0.061	0.062	0.044	0.040	0.056
	t-statistic	1.81	3.19**	5.12**	10.96**	5.70**	3.35**	6.67**	22.30**	24.22**	11.29**
	Adj. R <sup>2</sup>	0.01	0.04	0.11	0.36	0.13	0.05	0.17	0.70	0.74	0.38

Dec-2012	Estimate	0.20	0.12	0.03	0.65	0.21	0.054	0.55	0.31	0.39	0.63
	Std Error	0.043	0.065	0.017	0.067	0.063	0.064	0.057	0.060	0.059	0.059
	t-statistic	4.59**	1.81	2.00**	9.74**	3.40**	0.84	9.64**	5.23**	6.60**	10.62**
	Adj. R <sup>2</sup>	0.09	0.01	0.14	0.31	0.05	0.00	0.31	0.11	0.17	0.35

**Panel B: AMC**

Contracts		17:10	17:20	17:30	17:40	17:50	18:00
Dec-2009	Estimate	0.87	0.98	1.05	0.94	0.91	0.85
	Std Error	0.065	0.047	0.043	0.048	0.046	0.054
	t-statistic	13.30**	21.04**	24.43**	19.44**	19.62**	15.67**
	Adjusted R <sup>2</sup>	0.46	0.68	0.74	0.64	0.65	0.54
Dec-2010	Estimate	0.85	0.67	0.67	0.78	0.67	0.88
	Std Error	0.068	0.054	0.076	0.086	0.087	0.0753
	t-statistic	12.53**	12.35**	8.83**	9.01**	7.62**	11.66**
	Adjusted R <sup>2</sup>	0.68	0.60	0.42	0.45	0.37	0.65
Dec-2011	Estimate	0.95	0.47	0.85	0.93	0.70	1.07
	Std Error	0.171	0.083	0.12	0.071	0.172	0.067
	t-statistic	5.56**	5.63**	7.04**	13.10**	4.10**	15.91**
	Adjusted R <sup>2</sup>	0.48	0.49	0.58	0.83	0.30	0.92

	Estimate	0.83	0.32	0.68	0.54	0.63	0.87
	Std Error	0.093	0.082	0.0824	0.084	0.077	0.089
Dec-2012	t-statistic	8.88**	3.86**	8.28**	6.43**	8.13**	9.71**
	Adjusted R <sup>2</sup>	0.58	0.18	0.51	0.37	0.47	0.68

## 2.5. Conclusion

The EU-ETS was developed as the principal policy instrument to achieve the EU's obligations under the Kyoto protocol. The scheme has grown to become the world's largest carbon market. In 2009, it accounted for 96.46% of global allowances trades. Several other industrialised countries that must reduce their carbon emissions with respect to their Kyoto protocol commitments have shown interests in developing similar schemes to reduce their greenhouse gas emissions. Two have already passed legislations at the national level for this purpose and several more at municipal and state levels. The design and policy provisions of these schemes suggest a possible linkage with the EU-ETS and other similar schemes in the future. This is only rational because the most efficient manner of achieving stabilisation of green house gases in the atmosphere is through a unified policy mechanism. Considering its success so far, it is reasonable to assume that in the event that it occurs, a global mandatory carbon cap and trade scheme will be based on the EU-ETS model. If the EU-ETS will serve this purpose, there must be evidence of its efficiency.

According to Fama (1970), financial market efficiency is a function of incorporation of available information to determine instrument price. In this study, efficiency of the EU-ETS is inferred through the price discovery process. This study analyses intraday price discovery process on the EU-ETS's largest trading platform and also measures the efficiency of that process. The chapter provides an empirical connection between trading volumes of permit contracts in the EU-ETS and their contribution to price discovery and informational efficiency. In the study, evidence emerges that the more liquid permit instruments are, the higher the likelihood they can be traded efficiently. The price discovery process for relatively liquid instruments show levels of efficiency comparable to those of traditional financial instruments. This is the case during both normal trading day and after hours trading periods in the well traded contracts. This is a very significant indication of the level of maturity of the EU-ETS. The efficiency of the EU-ETS can therefore provide a basis for the introduction of a global mandatory cap and trade scheme. The findings have implications for practitioners and academics alike.

For compliance buyers of carbon permits, who must trade in the market or reduce their emissions to avoid regulatory penalties, these results potentially improves confidence in the EU-ETS. Compliance buyers can develop carbon trading strategies with better understanding

of the market price evolution. This includes the distinctions between the different carbon futures instruments and the different trading periods (and intervals).

For investors, this study provides practical insights that can be useful for carbon investment strategies and effective risk management. Investor participation in the market requires the assurance of an appreciable level of price signalling. This is vital for efficient allocation of resources. By demonstrating that liquid carbon futures enjoy similar level of informational efficiency, the study serves this purpose.

This study also adds to the growing body of literature seeking to understand the carbon trading market in Europe. The possibility of the EU-ETS serving as the platform for establishing a global market led mandatory carbon emissions reduction programme increases the important nature of work in this area.

The restriction of AMC trading/registration of trades on the ECX to EFP and EFS trades almost entirely ensures that this period on the market will be a session largely for professional traders. Trading EFP/EFS in the AMC period require the ownership of a platform account. Non-members must retain a clearing member in order to trade at this time. The EFP and EFS trades in the sample are large with more than 81% qualifying as block trades (based on ECX's definition of block trades as trade sizes of 50 lots or more) suggesting that the mechanism is almost an exclusive preserve of institutional investors, compliance participants and other professional traders. Kurov's (2008) analysis of three index futures markets reveals that 61% to 74% of the price discovery in these markets is from orders initiated by exchange member firms and that this information share exceeds the proportion of trading by them. Therefore they appear to be the most informed participants in the market. If this class of traders dominates the trades in the ICE/ECX carbon futures during the AMC market as Table 2.2 suggests, then the results are consistent with the Kurov (2008) (see also Kurov and Lasser, 2004). The findings that, there exists higher levels of informed trading in the AMC and that lower trading instruments are more likely to have higher levels of informed trading are also consistent with Barclay and Hendershott (2003).

The huge changes in market features observed at the close provide insights into the endogenous impacts of the AMC EFP/EFS trades in the general exchange traded emissions permit market. The AMC period has the largest volume of contracts traded per minute than



the RTH period but the reduced total number of trades executed within the period means that each trade becomes very informative. The increase in levels of informed trading starts inside the RTH at about 15:00hrs accelerates as the closing approaches and eventually peaking during the AMC period. The statistically significant high signal: noise ratios for the contracts in the AMC and the latter part of the normal trading day confirm this suggestion. A lot of trades during this period are largely executed to take advantage of private information. The restriction placed on AMC period price movements only serves to make this more remarkable.

Before now, no attention has been given to the huge impact of EFP and EFS trades in the EU-ETS. The analysis of these trades in the AMC on the largest carbon exchange in the world provides the first insight into how they alter the market characteristics. And also shows the periodic changes in market dynamics during the day and the AMC period.

Perhaps the most fundamental contribution made to academic literature with this study is the realisation of the interesting fact that normal trading day prices are noisier than after hours prices, but only on account of the less liquid contracts. Prices are more likely to be reversed in the normal trading day than in the AMC market, yet another confirmation of the high levels of informed EFP/EFS trades in the AMC.

However, while providing a major insight into variations of price discovery over the RTH on the world's largest carbon exchange, this study does little to resolve the lingering question of whether the large differences in price discovery is as a result of platform mechanism dissimilarities or actually the divergence in trades' core characteristics over the day.

### **3. Determinants of Price Impact of Block Trades on the ECX**

#### **3.1. Introduction**

Since the 1980s, equity markets' trades have become increasingly dominated by large institutional investors. Schwartz (1991) reports that an estimated 70% of trading volume recorded on major exchanges was executed by institutional investors by the late 1980s. Jain (2003) supports this claim. These trades are all block trades. The domination of the EU-ETS trading platforms by large traders should be expected given the structure and purpose of the scheme. Trading activity breakdown however suggests that if institutional traders do trade on the platform, they do so with stealth, using trade sizes not regarded as block (see discussions in chapter 2) or they just trade using the OTC mechanisms. OTC trades are the main avenue for institutional trading in the EU-ETS, with one estimate at 70% or more in Euro value (see Rittler, 2012).

For all stakeholders in financial markets, there has been a sustained need to fully comprehend the impact of block trading on market fundamentals and the likely determinants of such market reactions. This is particularly important in equity markets as there is a fundamental requirement for investors to have a level of confidence on the efficiency of the market. This efficiency is in regards to the ability of the market to incorporate information on the value of companies into their traded stocks (Fama, 1970). The notion that the prices displayed for stocks may be unrepresentative of the value of companies they represent, potentially erodes confidence in equity markets. Yet, financial markets being susceptible to changes in traded volumes from supply and demand sides are likely to react in such a way that will induce price asymmetry. That is changes in prices of instruments do not reflect changes in the value of the underlying but are due to temporary deviations as a result of variations in distribution. Price asymmetry therefore detracts from the real value of a company's stock and consequently becomes symptomatic of a less efficient market.

More relevantly, installations in the EU are required to reduce their emissions under the EU-ETS, to do this; there are a number of mechanisms to draw from. They can opt to cut their emissions or sustain/increase the current levels by buying emission permits to cover the shortfall in expected cuts. In order to make decisions on the best route to take, compliance buyers must have the same level of confidence that investors need in regular financial

markets, in the EU-ETS platforms. In other words, the platforms must efficiently incorporate information on value of emission permits for the scheme to work. This underscores the importance of understanding the behaviour of price under various conditions and this includes reaction to block trades. Several studies have extensively examined a number of factors that can potentially determine the extent of price impact and their relationships with price impact.

Chan and Lakonishok (1993) find a relationship between market capitalisation and price impact (see also Chan and Lakonishok, 1995). Ball and Finn (1989), in complete contradiction however report no price effects for large trades on the Sydney equity market. Large trades, according to the authors are also usually broken up to avoid price effects and the costs incurred as a result of trade fragmentation do not result in any price impact. The Sydney Stock exchange has since merged with other exchanges in Australia in 1987 to form the Australian Securities Exchange (ASX). Liquidity has thus improved, and a recent study by Frino et al. (2007) completely contradicts the findings of Ball and Finn (1989).

Holthausen et al. (1987) investigate price impacts due to block trades as well, showing that larger trades induce larger price impact than smaller trades. Barclay and Warner (1993), Chakravarty (2001) and Alzahrani et al. (2010) also provide evidence that order size and subsequent execution potentially results in corresponding trade price impact. In relation to temporary price impact, Holthausen et al. (1990) also examine the rate at which price reversals occur after they have been impacted by a block transaction. They find that most of the price adjustment after the block trade actually occurs during the very next trade and all price reversal is complete within a maximum of three trades (for purchases it takes only one trade). Their study however provides further evidence that majority of price impact induced by block trades are permanent and vary only according to size and not necessarily dependent on trade sign. The only evidence of asymmetry is in temporary price effects. Gemmill (1996) makes contradictory findings on the London Stock Exchange showing differences in magnitude of price impact as a function of trade sign. The study reports permanent price impacts due to block trades on the London Stock Exchange; the study finds a permanent impact equivalent to about 33% of the spread for purchase block trades and about 17% for sell block trades; however the sell block trade estimates are not significant.

Consistent with Gemmill (1996), most of the studies conducted on price impact of buyer and seller initiated block trades report price impact asymmetry between the two groups. They generally submit that prices appreciate after purchase block trades are executed and depreciate on sales. The depreciation that occurs after sell trades are executed suffers reversion but purchase block trade induced appreciations remains. Chan and Lakonishok (1993) argues the reason for this is that block sales have a higher likelihood of involving a broker (acting as an intermediary) than a block purchase, the temporary impact from sell trades is therefore a reflection of price concession as compensation for the intermediary role played by the broker.

Chan and Lakonishok (1995) extend the investigation into block trade price impact to include the identity of traders and find relationship between the identity of fund managers involved in trading and the degree of price impact induced by their trades. The study shows that trading costs associated with managers having higher demand for immediacy (growth aligned companies) is higher and hence their trades induce larger price impact than those with more muted demand for immediacy. Similar findings are made by Aitken and Frino (1996b) and Chiyachantana et al. (2004). An example of demand for immediacy leading to larger execution price (and by extension, price impact) is Loeb (1983) using quoted spreads of order sizes as proxy for trading costs.

Chan and Lakonishok (1997), Domowitz et al. (2001), Conrad et al. (2001), Chiyachantana et al. (2004) and Frino et al. (2007) find a positive relationship between volatility and price impact. The authors opined that higher volatility estimates are as a result of a high level of inconsistency in traders' beliefs and this raises the level of risk associated with the instrument. Risk-averse investors are as a result, less willing to trade and concessions will have to be afforded them to ensure their participation. The concession leads to price impact (Kraus and Stoll, 1972).

A number of studies including Aitken and Frino (1996b), Bonser-Neal et al. (1999), Chiyachantana et al. (2004), and Alzahrani et al. (2010) also examine if latent market shifts can explain price impact of block trades by using market indices as market return variable. Frino et al. (2007) use a more refined measure of market return computed over the same period as the employed price impact variables (total, permanent and temporary impacts). The

findings of these studies have similarities in that they corroborate reports of price impact asymmetry reported in the earlier studies.

Several other variables have been tested by researchers over the years to investigate the price impact of block trades. These include historical price performance (see as examples Jones and Lipson, 1999; Conrad et al., 2001; Frino et al., 2007; Alzahrani et al., 2010); bid-ask spread as proxy for instrument liquidity (see Aitken and Frino, 1996b; Gemmill, 1996; Frino et al., 2007; Alzahrani et al., 2010). Others conduct comparative analysis based on market design and trading platforms: Chan and Lakonishok (1997) compare the NYSE and NASDAQ finding discrepancies in execution costs along the lines of platform expertise. Keim and Madhavan (1996) compare the upstairs and downstairs market using a unique dataset comprising of both on-screen and OTC trades.

Report of a U-shaped intraday bid-ask spread pattern by McNish and Wood (1992) hint at a possible time dependent behaviour for price impact of block trades. This is because bid-ask spread is a popular proxy for measuring liquidity and liquidity has been shown to affect block trades' price impact. Frino et al. (2007) examine this on the Australian Stock Exchange and Alzahrani et al. (2010) carry out the similar investigations on the Saudi Stock Market. They both document time of day effects for price impact of block trades. Also, Kyle (1985), Easley and O'Hara (1987) and Glosten and Harris (1988) all suggest that for regular trades, the price impact is associated with trading spreads.

As evidenced from the studies reviewed above, price impact of block trades have been extensively researched for customary markets; however no study to this researcher's knowledge has been published for block trade price impacts in permit markets. This study therefore attempts an analysis of determinants of price impact in the EU-ETS using data from the scheme's largest platform, the ECX. This study is further informed by the increasingly large number of block trades in the EU-ETS. In 2005, approximately 80% of EU-ETS trades occurred OTC, most of these trades meet ECX's definition of block trades. The volume traded OTC progressively decreased to average approximately 70% of total transactions value over the entire course of Phase I. By January 2010, the proportion of exchange based trades in the scheme had reached 50% according to World Bank estimates (see Kossoy and Ambrosi, 2010). This rebalancing is informed by the desire of participants to avoid counterparty risks, an issue that has taken on greater significance in derivative markets as a

whole. The study mainly develops on the contributions of Frino et al. (2007) and Alzahrani et al. (2010) with complete focus on the downstairs market. The study also improves literature by employing an innovative measure of turnover as a matter of necessity and introduces a more specific measure of market return than most of the previous studies.

The results show intriguing patterns that largely contradict earlier studies from customary markets. For permanent and temporary effects, several instances of price impact asymmetry for block purchases and sales are found. Contrary to earlier studies, wider spreads are associated with smaller price impacts. These findings can be attributed to the fact that block trades executed after a price run up induce smaller price impact, as suggested by Saar (2001) and as displayed in the sample. The implication here is that liquidity concerns in the EU-ETS play a less prominent role in emissions permits pricing than in customary markets. This is underscored by the price discovery study in chapter 2 showing that small amounts of trading can generate very large proportion of price discovery in the EU-ETS. Short run improvements in liquidity, although an important factor in market efficiency (see Chordia et al., 2008), do not detract from block trade price impact on the world's largest carbon platform. The findings have implications for compliance traders and policy makers alike. It is important that in designing future phases of the EU-ETS, these aspects of the results should be considered.

The remainder of this chapter is structured as follows. In section 3.2, the set up of the ECX with respect to block trading is discussed. Section 3.3 presents the data and methodology; section 3.4 discusses sample selection, descriptive analysis and presents the regressions results along with discussions and section 3.5 concludes.

## **3.2. Background to Study**

### **3.2.1. Institutional Set-up**

The ECX is the largest carbon exchange in the world by volume and value, with 92% of EU-ETS on-screen trades registered on the platform in 2010. The ECX is a member of the Climate Exchange Plc group of companies, which also includes the Chicago Climate Exchange (CCX) and the Chicago Climate Futures Exchange (CCFX). It manages the development and marketing of several carbon derivative instruments listed and traded on the

Intercontinental Exchange platform (ICE Futures Europe). Investors and compliance buyers trade on the ICE platform, in three different types of derivatives (futures, daily futures and options) that have as underlying either EUAs or CERs.

Trading in the first carbon financial instrument (CFI) floated on the platform commenced on Friday 22<sup>nd</sup> April 2005. This was the ECX EUA Futures contract with December 2005 maturity. Apart from the ECX EUA Futures contracts, there are other CFIs on offer. EUA Options contract was introduced on 13 October 2006 and the ECX CER Futures contract on Friday 14 March 2008 with the December 2008 maturity contract. The Options contract variant of the CER units was subsequently introduced on 16 May 2008. More recently (13<sup>th</sup> March 2009), the exchange introduced EUA and CER Daily Futures contracts, a move interpreted by analysts as an attempt to compete in the carbon spot market which is currently dominated by Paris based Bluenext. With the exception of the daily futures contracts, all contracts up to June 2013 are listed on quarterly maturity cycle. The 2014 to 2020 expiration contracts are listed on annual expiry (December) for the time being. However, trading almost exclusively occur on the December maturity contracts alone with the nearest December maturity usually accounting for more than 80% of trading volume. A similar observations is made for the EEX study in chapter 4, while Mizrach and Otsubo (2011) report the same phenomenon for the ECX.

Trading rules and procedures on the exchange follow general industry practice in the more traditional asset classes. Trading commences at 07:00 and continues until 17:00 hours UK local time. There is a pre-trading period of 15 minutes from 06:45 hours to allow members place orders in preparation for trading start, however almost no orders are executed during this period. The settlement period, which runs from 16:50:00 to 16:59:59 hours UK time, is the third stage of the trading day and is used for determination of the settlement price. The fourth stage of the trading is the after-hours period reserved only for reporting Exchange for Physical/Swaps (EFP/EFS) trades. In chapter 2 of this thesis, the contribution of trades reported during this period to price discovery is examined. These trades can be regarded as a form of ‘upstairs’ trading in the context of the ECX and hence will not be examined in this study since the focus is on downstairs trading only. This follows the precedent of Frino et al. (2007) and Alzahrani et al. (2010).

Trading occurs both directly on the platform and bilaterally off the platform (then registered on the platform for on-screen registration). By virtue of this, the exchange maintains three trading mechanisms: trades occur on the ICE platform (an electronic trading system (ETS)), by EFP/EFS trades; or through the Block Trade Mechanism. A mobile version of the ETS has been made available through smart phone application called mobile ICE.

Although, the larger value of trades occur off the platform as OTC trades, higher number of trades are executed on the platform. Trading on the ICE platform is open only to ICE Futures Europe members with emissions trading privilege and have also previously listed a minimum of one trading personnel with the ECX. This person is known to the exchange as a 'Responsible Individual (RI)'. For institutional traders with General and Trade Participant memberships, there is no limit to the number RIs registered with the exchange, however Individual Participant members must register only one RI. The RI is the trader known to the exchange and must abide with exchange set rules as well as attain a level of trading competence before admission. Non-members of the exchange can however be involved in order routing by using the ICE Platform's front end application called WebICE and through other similar applications provided by Independent Software Vendors (ISVs) accredited by the exchange. These non-members must be clients of members who have already gained their consent to use the application for order routing.

Participants submit orders by entering it into the ETS, the trades executed as a consequence of orders are deemed to be anonymous by exchange rules. The executed trades go via the trade registration system (TRS) for account allocation. Usually account references are inputted pre-execution but this can also be done post-execution. Price transparency is ensured by the availability of real-time prices made available on ICE Platform screens and vendor sources. These vendors include Bloomberg, CQG, E-Signal/FutureSource, Reuters, IDC and ICE Live.

The exchange sets reasonability limits for purchase and sale orders. A purchase (sale) order above (below) the limit is rejected. Sale (purchase) order above (below) the limit is accepted without being executed except the market shifts to alter the reasonability limits and hence places it within the limit. The exchange also maintains a 'no cancellation range' within which trades reported as mistakes may not be cancelled. This rule enhances market confidence and reduces noise trades.



Although trading commences at 7:00 hours UK local time, morning markers are not set until after 09:15 hours, it is the weighted mean of trades occurring within the fifteen minute period of 09:00-09:15 hours. And it is calculated for only December maturity EUA Futures Contracts. Individual contract indexes are issued after the close of after hours trading at 18:00hrs for both CER and EUA Futures contracts with December maturities. Open interest, which gives an indication of market depth, is computed at 10:00 hours and released at 11:00 hours UK local time each trading day. It is representative of the previous close's position, adjusted for after-hours trading and transfers/settlements completed before 10:00 hours.

Clearing is provided by Ice Clear Europe, which charges transaction fees on behalf of the exchange. For quarterly contracts, a currently prevailing charge of €0.0035 per tonne of CO<sub>2</sub> (one EUA) for proprietary transactions and €0.004 for non-proprietary transactions are levied on clearing members. The charges are doubled for daily futures contracts. These fees are in addition to annual subscription fees for various participant categories. Transaction fees are not placed on the exercise of an option or on physical delivery of futures contracts. Minimum tick has been held constant at €0.01 per tonne of CO<sub>2</sub> since 27<sup>th</sup> March 2007 from its previous €0.05 at commencement in 2005.

Trading in contracts cease on the last trading Monday of the expiry month and the underlyings are thereafter eligible for delivery within 72 hours of trading cessation. Since Ice Clear Europe acts as the clearing agent, physical delivery of contracts' underlyings are effected through them. By nature of the EU-ETS, Clearing members are required to own a Person Holding Account (PHA) with a country registry within the EU-ETS. The transfer of EUAs and CERs are made from the PHA account of the selling Clearing member onto the PHA of Ice Clear Europe, then from theirs to the buying party's PHA. All 27 EU registries are currently eligible for physical deliveries under this arrangement. All registries operate on a continuous basis and are connected to the CITL. Transfer of permit rights are done online real time hence CITL usually confirms receipt of transfer requests within 60 seconds. However, CITL must conduct further checks to confirm the authenticity of the request and validity of the permits being traded. This can take up to 24 hours. The need for these robust checks has assumed a larger dimension since January of 2011 when more than €30 million worth of permits were stolen from registries across the EU.

The ECX has a defined minimum lot quantity for block trades. Each block trade must be a minimum of 50 lots/contracts (50,000 EUAs or CERs).

### **3.3. Data and Methodology**

#### **3.3.1. Data**

Two datasets are obtained; the first is high frequency data from the ICE Futures Europe detailing intraday transactions to the nearest second. The fields contained in this dataset are the time of trade execution to the nearest second, numeric identification for the CFI, the CFI description, traded month of contract, order identification, trade sign (bid/offer), transaction price, quantity traded and the type of trade (exchange/OTC/Block etc). The dataset covers from the start of Phase II EU-ETS (2<sup>nd</sup> January, 2008) until the 9<sup>th</sup> May 2011. The use of the dataset ensures that this study provides the longest time period analysis of Phase II EU-ETS trading till date.

The second dataset contains EOD variables, it is also from ICE Futures Europe and covers the same time span and provides daily computations of different variables. The variables are contract specific and include open interest, exchange derived value weighted indices, settlement price and daily traded volumes.

Only the December expiry contracts are selected because they are the only ones for which official exchange index data is available for, the December maturity contracts are for 2008, 2009, 2010, 2011, 2012, and 2013 expiries are thus selected. This selection is also based on volume considerations. Apart from the non-December contract trades, other trades are also removed following from previous studies as earlier articulated. All trades executed within the initial pre-open period and during the after-hours market are excluded. All other trades executed off market and in upstairs market are also excluded. These steps are taken to provide basis for comparing this study's results with previous studies, also to ensure robustness and consistency.

After cleaning, the final dataset consists of a total of 961,131 trades over the entire period. This study follows ECX's definition of block trade as any trade with a minimum lot size of 50 contracts (50,000 EUAs). This definition yields a sample size of 16,715 block trades. This

is about 1.74% of the total number of trades in the cleaned dataset. The absolute quantity is comparable to the 16,951 NYSE downstairs block trades analysed by Madhavan and Cheng (1997) for 30 Dow Jones stocks and larger than the sample of 5987 from the London Stock Exchange investigated by Gemmill (1996). Further, considering that permit market trading activities are considerably lower to the traditional asset classes; this can be regarded as a substantial quantity. Also the percentage of block trades to all other trades is comparable to the Frino et al.'s (2007) adoption of the largest 1% of trades as block trades.

Trade signs allocated to each trade by the exchange are adopted for the final tick data set.<sup>13</sup> Of the 16,715 block trades in the final sample, 8356 are buyer initiated and 8359 seller initiated. As in Frino et al. (2007), the volume of seller initiated orders are slightly more than that of the buyer initiated ones.

### 3.3.2. Methodology

The inquiry begins with the computation of three types of price impacts generally recognised in literature. These are the total price impact, the permanent price impact and the temporary price impact. Microstructure literature acknowledges permanent price impacts as those occasioned by trades with private information and temporary price impacts as those resulting from noisiness in trading leading to reversal of price (see Glosten and Harris, 1988; Chan and Lakonishok, 1995; Easley et al., 2002). This researcher follows Holthausen et al. (1990), Gemmill (1996), Frino et al. (2007) and Alzahrani et al. (2010) in using the five-trade standard to compute the price impact measures. The study ensures comparability by calculating all three measures as percentage returns according to equations (3.1), (3.2) and (3.3):

$$Total\ Impact = \frac{P_t - P_{t-5}}{P_{t-5}} \quad (3.1)$$

$$Temporary\ Impact = \frac{P_{t+5} - P_t}{P_t} \quad (3.2)$$

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<sup>13</sup> The tick rule (Lee and Ready, 1991) is also employed with very similar trade sign classification portioning.

$$\text{Permanent Impact} = \frac{P_{t+5} - P_{t-5}}{P_{t-5}} \quad (3.3)$$

The total price impact is the percentage return from the block trade to five trades before the block trade. The permanent price impact is the percentage return from five trades before the block transaction to five trades after the block transaction. Finally, the temporary price impact is measured as the percentage return from the block transaction to five trades after it. Transaction prices are used in the absence of direct quotes.

This study adopts the model of Frino et al. (2007), thereafter employed to good effect by Alzahrani et al. (2010) in examining some likely determinants of block trade impact on the ECX. Accordingly, the following time series regression is estimated with EUA contracts-specific variables using OLS and the Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$\text{Price Impact} = \alpha + \beta_1 \ln(\text{SZ}) + \beta_2 \text{SD} + \beta_3 \ln(\text{TO}) + \beta_4 \text{MR} + \beta_5 \text{MO} + \beta_6 \text{BAS} + \varepsilon \quad (3.4)$$

Where price impact corresponds to one of three price impact measures: total price impact, permanent price impact and temporary price impact. And the explanatory variables are computed as follows:

**Size (SZ)** corresponds to the natural logarithm of volume of contracts contained in the block transaction. Based on the assumption that trade size corresponds to information content (see Kraus and Stoll, 1972; Easley and O'Hara, 1987; Chan and Lakonishok, 1993 and others), trade size is adopted as a proxy for information content of the block trade. When investors have private information on an instrument, they act based on the new belief the information establishes for them. Hence they place a sell order if the belief is that the instrument is overpriced or purchase if the instrument is underpriced (see Madhavan et al., 1997). Following from this, block trade size is assumed to have a direct impact on price changes, hence its inclusion in the model.

**Volatility (SD)** represents the standard deviation of trade execution price returns for the trading day up until the block trade.<sup>14</sup> This measure is in line with previous studies (see for example Frino et al., 2007). Volatility is representative of intraday fluctuation in trading prices; it shows the pattern of trading belief over the course of a trading session, and can therefore be regarded as an implicit proxy of adverse selection costs of trading. The higher the level of volatility of an instrument, the greater the risk associated with it, thus leading to wider spreads as compensation for trading (see Sarr and Lybek, 2002). The onset of larger spreads on account of volatility suggests that volatility will lead to price impacts. It is expected that volatility of the futures contracts will be positively related to price impact as a result (Domowitz et al., 2001).

**Turnover (TO)** represents the natural logarithm of aggregate Euro value of all futures contracts traded on the trading day prior to the execution of the block trade divided by the prevailing Euro volume of open interest. Turnover has been regularly employed as a measure of trading activity and market liquidity (see among others Lakonishok and Lev, 1987; Hu, 1997; Frino et al., 2007). Further, open interest has been established as a component of market liquidity measures in futures markets. Using open interest as a component of the proxy for market depth (liquidity) follows after Bessembinder and Seguin (1993; 1992) and Fung and Patterson (1999). Open interest is a reflection of order flow of trades and readiness of traders to risk their funds and therefore has similar levels of correlation with volatility that spreads have. Price impact is expected to be lower with improvements in liquidity; hence we anticipate a negative relationship with price impact.<sup>15</sup>

**Momentum (MO)** is computed as the lagged cumulative daily return for each contract on five trading days prior to the trading day of the block trade. This expresses the trading trend for the specific instrument. Higher returns will indicate a purchasing trend and lower returns, a selling trend. Saar (2001) submits that price performance history of an instrument is related to its expected price impact asymmetry. Specifically, block trades that are executed on the back of decreasing price performance will manifest higher positive asymmetry, and block trades executed after a strong run of price appreciation should exhibit less impact or possibly

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<sup>14</sup> Standard deviation of the execution price of trades is also used for the first round of regressions, in line with Alzahrani et al. (2010). The results are quantitatively similar.

<sup>15</sup> Open interest on its own as measure of liquidity was also used; however the results obtained are less significant across all the models, hence it is not a preferred stand alone variable.

negative asymmetry. Since the transitioning to Phase II in the EU-ETS, the market has witnessed both stronger liquidity and market efficiency as earlier stated and hence has largely been on a run up in terms of price performance. Based on this, it is anticipated that momentum will yield predominantly negative price impact coefficients.

**BAS** is a second measure of liquidity in the model. Relative bid-ask spread is the prevailing relative bid-ask spread when the block transaction is executed. High price impact is expected to be associated with wider spreads than lower price impact i.e. when spreads are wide, there would be higher price impact than when they narrow. Relative bid-ask spread is computed as the prevailing traded ask price at the time of the block trade minus the traded bid price, then divided by the average of the ask and bid prices.

**Market Return (MR)** represents the contract-specific daily return on ECX EUA index for each contract. This is a more robust approach than previous studies. By adopting contract specific return this study emulates Frino et al. (2007) in using a more refined measure of market return. Huang and Stoll (1997) argue that the price of an instrument is a function of trading activities in the instrument and others in a specific portfolio or market. The impact of market return can therefore be inferred through the use of contract specific index.

**Time of Day dummy (TimeDum, TD)** variables are created to capture the time of day effects. Alzahrani et al. (2010) and Frino et al. (2007) report intraday differences in level of block trade asymmetry effects. For consistency and completeness, the time of day dummies are introduced to test for these effects on block trades on the ECX. Analogous to previous studies, the trading day is split into three intervals. On the ECX, the normal trading day is from 07:00 hours to 17:00 hours UK local time. TimeDum<sub>1</sub> takes the value of one if the block trade occurs between 07:00 and 08:00 hours and value 0 otherwise. TimeDum<sub>2</sub> takes the value of one if the block trade occurs during the middle of the trading day (08:01-16:00 hours UK time) and 0 otherwise. The third interval of the day, the final hour of trading day (16:01-17:00 hours) is not represented in the regression results because it is the reference group of block trades and takes the value of 0.

## 3.4. Results and Discussion

### 3.4.1. Descriptive Statistics

Panel A of Table 3.1 shows descriptive statistics based on the volume of trade classification. Of the 16,715 block trades in our final sample, 8356 are buyer initiated and 8359 seller initiated.

Total volume of block trades to the total number of trades in the sample is 1.74%. In comparison, trading in a permit market like the ECX seems to be less dependent on institutional activity. This is however, only if we equate block trading activity to institutional activity. The nature of the EU-ETS is such that emissions are capped and traded in the upstream; hence trading in EU-ETS permits is dominated primarily by both installations trading for compliance purposes and other institutional investors such as Barclays Capital. The current situation is that most of these institutional activities are not exchange based, they occur mainly on OTC basis. While forming only a small portion of EUA trades (13%) on the ECX, they account for a far higher proportion of Euro volume of trades (see Mizrach and Otsubo, 2011; Ibikunle et al., 2012).

0.869% of all the trades in the final sample are identified as buyer initiated block trades while a slightly higher percentage of 0.87% are seller initiated block trades. This trend while conforming to some previous studies (for example Frino et al., 2007), contrasts with others (see for example Gregoriou, 2008). The average values of price impact for both classes of trades are -0.036% for purchases and 0.038% for sales. The direction of the impacts, while in contrast with Alzahrani et al. (2010), is the first suggestion of the existence of price impact asymmetry in the sample. The average price impact for the entire block trades is however lower than expected at 0.001% considering the size of the block sales (and in comparison to block purchases). The suggestion here is that the block purchases neutralise the impact of sells leading to lower than expected estimates for all block trades, this issue is examined closely in subsequent analysis. Although, having a higher number of seller-initiated block trades conform to a number of previous studies, the higher average level of price impact for block sales suggest that there should be a higher volume of purchase trades since less price impact occurs on purchase trades. This argument however only holds if the price impact is positive for purchases and negative for sales as is usually the case in most studies of equity classes. Further analysis will shed more light on this issue.

**Table 3.1 Summary statistics for Block Trades**

The table shows descriptive statistics for block trades of December maturity EUA Futures executed on the European Climate Exchange (ECX) platform between January 2008 and April 2012. Panel A reports the proportion of trades and trading activity measures. Panel B also reports trading activity measures with mean average bid-ask spread estimates. Standard deviation measures the standard deviation of percentage price impact.

**Panel A**

	<b>Number of trades</b>	<b>% of total number of trades</b>	<b>Price impact</b>	<b>Standard deviation</b>
<b>All trades</b>	961131			
<b>Block trades</b>	16715	1.74	0.001	0.005
<b>Block purchases</b>	8356	0.87	-0.036	0.006
<b>Block sales</b>	8359	0.87	0.038	0.003

**Panel B**

	<b>Number of trades</b>	<b>Average number of contracts/trade</b>	<b>Average transaction Value/trade (€ '000)</b>	<b>Average Relative Spread (%)</b>
<b>All trades</b>	961131	6.79	108.40	0.07
<b>Block trades</b>	16715	78.94	1232.71	0.06
<b>Block purchases</b>	8356	80.21	1258.03	0.07
<b>Block sales</b>	8359	77.67	1207.40	0.06

Further descriptive characteristics are provided in Panel B of Table 3.1. This panel shows description using trading activity and liquidity (relative bid-ask spread) measures. After removal of the high volume EFP/EFS trades from the on-screen block trades, a total of 16,715 block trades with a combined value of about €21 billion is obtained. For all block trades, average number of contracts per trade is more than 13 times the value for all trades combined. The average number of trades (transaction value) for block purchases is higher than sales at 80.21 (€1,258,030) and 77.67 (€1,207,400) respectively. This trend is consistent with previous studies. The average relative bid-ask spread value is €0.00067 for purchases and €0.00056 for sales. The average relative bid-ask spreads for all trades compare



favourably with those of all block trades, in fact, with the exception of block purchases, the spread for all trades is higher than all classes in Panel B of Table 3.1. For more developed markets and traditional asset classes, the expectation would be to have reduced spreads for all trades and larger spreads for block trades since they are more likely to be influenced by private information rather than search for liquidity. A number of microstructure studies suggest strongly that large sized trades are more likely to contain higher level of information than smaller ones (see Easley and O'Hara, 1987). Investors have however been known to fragment trades over specific timeframes to take advantage of private information rather than make a huge trade in order to avoid revealing the privately held information before they can take advantage. Information content can however still be inferred by direction of trade over time (see for example Easley et al., 1996; Madhavan et al., 1997).

To some extent, the results in Panel B of Table 3.1, showing block purchases with higher average number of contracts per trade seem to confirm this intuition. But, it is also noted that all trades with about 11 times smaller average trade size than block trades has slightly higher average relative spread. An explanation is possibly the relatively noisy nature of price discovery during the trading day on the ECX. Noise in price discovery and information asymmetry on the ECX has been documented by Ibikunle et al. (2012); the study along with others (such as Mizrach and Otsubo, 2011; Frino et al., 2010; Benz and Klar, 2008) provides a starting point to understanding the microstructure properties of this market.

### **3.4.2. Regression Results and Discussion**

Table 3.2 reports the estimation results of equation (3.4) for the whole block trades sample without the time of day dummy variables. Panel A shows the mean price impact of the three types of price asymmetry impacts employed as independent variables: temporary, permanent and total price impacts. All values are positive but none are significant at any of the constructed levels (1%, 5%, and 10%). The estimates border on the 10% significance level. Results show higher levels of price impact for permanent effects than temporary effects at 0.00021% to 0.00018%. Although both values are low in comparison to previous studies and also statistically insignificant, the result still is a suggestion that informed trades are likely to leave higher impacts on price than liquidity driven trades.

Panel B reports the regression coefficient estimates for the independent variables. Total impact coefficient estimates for all of market return, momentum and relative bid-ask spread variables are significant at 1% levels. Trade size has a direct negative relationship with price impact, the estimates are however not significant at any of the tested levels of significance. For this variable, the permanent and temporary effects are very similar; the standard error estimates are also similar. Volatility measures the extent of market risks faced by market participants and is expected to have a positive relationship with price impact. The volatility coefficient estimates show that there is a general positive relationship with price impact for all three types of effects. The permanent effects coefficient is significant at 10% level and the temporary effects estimate at 5% level. Again the estimates and standard errors are similar; however the temporary effects estimate is higher than the permanent effects estimate. This indicates that a higher proportion of price impact due to volatility is temporary.

Turnover estimates are positive but none are statistically significant. The very low positive estimates suggest that liquidity improvements do not reduce block trade price impact and may actually aid it. However, this is far from certain as the estimates do not even border on significance. Market return is the only variable to be statistically significant across the full range of effects. Statistically significant positive effects on price impact are observed for both permanent and temporary effects; and negative effect on price impact for total effects, this is also significant at 1% level. Positive Marketreturn estimates for permanent and temporary effects mean the price impact for block purchases is higher than that of block sales. This could explain the neutralising effect of block purchases hinted at in Panel A of Table 3.1. If block purchases are associated with higher impact than sales, then one can expect that under close examination of all/combined trades, the impact of purchases would dominate that of sales. This indicates that higher premium is paid by buyers when they initiate the trade than when sellers initiate the trade. The significant negative total effects estimate however calls this conclusion into question and will be examined more closely in succeeding analyses when trade sign dependencies are examined.

As expected, based on the returns trend on the ECX, momentum has negative effects on price impact for the full range of effects tested. The total effects estimate is significant at 1% level. Wider spreads are expected to have a positive relationship with price impact and narrow spreads, negative relationship with price impact (representative of high levels of liquidity). Only the total effects coefficient estimate (-0.05176) is significant at 1% level and it shows a

negative effect on price impact. Alzahrani et al. (2010) report identical results with temporary effects having a positive relationship with BAS and permanent effects, a negative relationship. The result implies that wider spreads are positively related with only temporary price impact. When the price impact is permanent, it is characterised by narrow spreads.

**Table 3.2. Determinants of Price Impact of Block Trades**

The table reports regression results and price impact estimates for block trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. The coefficients are reported along with the standard errors (in parenthesis). The following regression is estimated using OLS and also with Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$\text{Price Impact} = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \varepsilon$$

where Price Impact corresponds to permanent, total and temporary price impacts. Size represents the natural logarithm of the number of December maturity futures contracts for each block trade; Volatility is the standard deviation of trade to trade returns prior to the block trade on the trading day; Turnover is the natural logarithm of the futures contracts turnover on the trading day prior to the block trade, turnover is calculation as a ratio of total trade volume prior to the block to the prevailing open interest estimates; Market return is the return of EUA futures contract specific index computed by the ECX; Momentum corresponds to the cumulative return on the specific EUA Futures contract in the five days prior to the block trade; BAS is the prevailing relative bid-ask spread at the time the block trade is executed, BAS is measured as the last ask price prior to the block trade minus the last bid price before the block trade divided by the average of both prices. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey LM test statistics respectively. Panel A reports the price impact estimates and Panel B, the regression results. One EUA Futures contract has an underlying of 1000 EUAs. \*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

**Panel A: Price impact estimates**

Variables	Permanent effects	Total effects	Temporary effects
Mean estimates	2.12E-06	1.21E-05	1.76E-06

**Panel B: Regression Results**

Size	-2.23E-04 (0.0002)	-1.55E-05 (7.11E-05)	-2.04E-04 (0.0002)
Volatility	<b>0.1231*</b> (0.0678)	0.0136 (0.0232)	<b>0.1362**</b> (0.0688)
Turnover	0.0001 (8.40E-05)	2.22E-05 (2.88E-05)	9.41E-05 (8.52E-05)
Market return	<b>0.0138***</b> (0.0051)	<b>-0.0063***</b> (0.0017)	<b>0.02001***</b> (0.0052)
Momentum	-0.0031 (0.0024)	<b>-0.0027***</b> (0.0008)	-0.0007 (0.0024)
BAS	-0.0360 (0.058404)	<b>-0.0518***</b> (0.0200)	0.0275 (0.0592)
Observations	<b>16715</b>	<b>16715</b>	<b>16715</b>

<b>R-Squared</b>	0.0008	0.0024	0.0014
<b>BG-LM</b>	0.19	0.14	0.10
<b>BPG</b>	0.11	0.18	0.29

**Panel C: Correlation Matrix for Determinants**

	<b>BAS</b>	<b>Market Return</b>	<b>Momentum</b>	<b>Volatility</b>	<b>Size</b>	<b>Turnover</b>
<b>BAS</b>	1					
<b>Market Return</b>	-0.017	1				
<b>Momentum</b>	-0.023	0.261	1			
<b>Volatility</b>	0.322	0.001	-0.041	1		
<b>Size</b>	-0.012	0.016	-0.002	-0.019	1	
<b>Turnover</b>	-0.080	0.076	0.152	-0.257	0.006	1

A general observation in Table 3.2 is the suggestion that block trades have generally low impact on price when executed on the ECX since majority of the coefficient estimates are not statistically significant. The inferences from the results are tempered by this realisation. Notwithstanding, this study presents enough evidence to suggest that there is reduced price impact when the price return is on a run-up and that wider spreads lead to temporary price impact. There is also evidence indicating higher volatility and positive market return may drive up premium thus leading to larger price impact when block trades are executed. Panel C confirms that the degree of multicollinearity for the variables is very low. Consistent with previous studies, the determinants of price impact of block trades for purchase and sell transactions are investigated separately in section 3.4.3.

### 3.4.3. Price Impact and Trade Sign

Consistent with previous studies, the determinants of price impact of block trades for purchase and sell transactions are investigated separately in this section, and the results are displayed in Table 3.3. The intercept of permanent price impact for sell block trades in Table 3.3 is 0.00153 and this is statistically significant at 1% level, for the temporary price effect, the value is 0.000693 and it is also statistically significant at 10% level. The estimates indicate that the permanent price impact value is more than twice that of the temporary price impact, supporting the hypothesis that the ECX is more reactive to informed block sell trades execution than liquidity induced ones. Informed block trades have a higher likelihood of inflicting permanent price shifts. The mean total effects on price impact for sell block trades is also statistically significant at 1% level, the estimate is 0.00084. For purchase trades, none of the coefficient estimates are significantly different from zero. Although the permanent price impact (0.000949) is lower than the temporary permanent price impact (0.001554), the values are comparable.

Coefficient estimates for sell block trade size are all highly statistically significant and negative, with the permanent and temporary effects being significant at 1% level. The coefficients show that larger sell block trades have both permanent and temporary impacts on price of carbon futures on the ECX. Volume of executed trades is therefore a function of price impact for sell block trades. The relationship is significantly negative. Coefficient estimates for purchase block trades are not significantly different from zero.

Volatility is measured as standard deviation of price returns. Two of the coefficient estimates for purchase block trades are positive with one of them, temporary effects being statistically significant at 5% level, the total effect is however negative and also significant at same level. Total effects coefficient estimate for the sell trades is statistically significant at 1% level. This along with the negative purchase trades estimate contrasts with existing literature based on investigations from more traditional financial platforms. The positive permanent and (significant) temporary effects estimates for the purchase trades are however consistent with current literature (see for example Alzahrani et al., 2010; Chiyachantana et al., 2004). Volatility as a measure of variation in belief held by market participants is a proxy for the level of participatory risk in the market, hence it is hypothesised that the higher the volatility, the stronger the block trade price impact. The estimates for volatility provide evidence to

both support and contradict this belief. Results provide evidence that, for block purchases, higher volatility is a significant and positive function of temporary price impact. The total effects estimate is a contradiction of this reasoning. The permanent effects coefficient estimate is not significant but it is positive. Using the total effects estimate (the only significant volatility estimate), for sell block trades, volatility is positively related with price impact.

Open interest is used in computing turnover estimates. Open interest has generally been used in computing liquidity (depth) measures (see Bessembinder and Seguin, 1993; Fung and Patterson, 1999). Hu (1997) argues in favour of turnover as liquidity measure and has also shown evidence that liquidity has a negative relationship with equity returns. Existing literature suggests increased depth (liquidity) reduces block trade price impact. Results in Table 3.3 indicate that the ECX bucks this suggestion. The table reports positive coefficient estimates for permanent effects and temporary effects on price impact for purchase trades and negative estimates for block sell trades. All four estimates are significant at varying levels of significance. This result contradicts Frino et al. (2007), but is consistent with a section of results obtained by Alzahrani et al. (2010) on the Saudi Stock Market (SSM). They suggest that huge block sell trades in actively traded instruments may signal adverse information on intent of the trades. This is seemingly because they indicate moves of informed participants and consequently result in increase in instrument sales. This can result in the intensification of price impact of the block trades involved.

Positive market return coefficient estimates indicate larger price impacts for purchase block trades and more reduced impact for block sell trades. The results obtained are largely in keeping with this. Market return estimates for five of the coefficients are statistically significant at 1% level. They are positive for the full range of price effects for the block sell trades; this is consistent with Frino et al. (2007) and Alzahrani et al. (2010). The permanent effects and temporary effects estimates for the purchase trades are positive as well with the temporary effect estimate also being significant at 1% level.

According to Chiyachantana et al. (2004), institutional block trades, executed on the back of several days of positive price appreciation lead to lesser permanent price shifts. This corroborates Saar (2001) who reports that block trades executed following a recent price run-up generate smaller price impact. The results in Table 3.3 mirror that in Panel B of Table 3.2

and therefore for the most part remain consistent with this argument. Of the three types of effects tested only the total effects coefficient estimates however show statistically significant results. The total effects coefficient estimate for purchase block trades is negative and statistically significant at 1% level, indicating lesser price impact as a result of price run-up. The negative and significant sell coefficient (total effects) implies the opposite trend is true for sell block trades.

The BAS coefficient estimates are positive and significant at 1% level for permanent and total effects for sell block trades. The total effects BAS estimate for purchase block trades is also significant at 1% level but otherwise negative. Other coefficient estimates are statistically insignificant. The BAS estimates that are statistically significant convey the impression that with wider spreads there is evidence of reduced price impact for both purchase and sell trades and therefore narrower spreads are associated with greater price impact. This contradicts previous studies (see as examples Aitken and Frino, 1996b; Gemmill, 1996) but is consistent with results earlier reported in Table 3.2. The ECX is a platform created for trading emission permits (products of an emissions-constrained economy) unlike more traditional instruments. Emission permits are for submission only once a year but the market has been reasonably liquid all year round since the commencement of Phase II of the EU-ETS (see Montagnoli and de Vries, 2010; Ibikunle et al., 2012). Trading in emission permit instruments when they are not immediately needed for submission to the regulatory authorities may indicate a level of informed trading. Based on this reasoning, high levels of liquidity may lead to increased price impact for both purchase and sell block trades. This result corroborates the estimates obtained for the turnover variable. The turnover measure is also a liquidity variable.



**Table 3.3. Determinants of Price Impact of Buyer and Seller Initiated Block Trades**

The table reports regression results for buyer and seller initiated block trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. The coefficients are reported along with the standard errors (in parenthesis). The following regression is estimated using OLS and also with Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$PriceImpact = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \varepsilon$$

where Price Impact corresponds to permanent, total and temporary price impacts. Size represents the natural logarithm of the number of December maturity futures contracts for each block trade; Volatility is the standard deviation of trade to trade returns prior to the block trade on the trading day; Turnover is the natural logarithm of the futures contracts turnover on the trading day prior to the block trade, turnover is calculation as a ratio of total trade volume prior to the block to the prevailing open interest estimates; Market return is the return of EUA Futures contract specific index computed by the ECX; Momentum corresponds to the cumulative return on the specific EUA Futures contract in the five days prior to the block trade; BAS is the prevailing relative bid-ask spread at the time the block trade is executed, BAS is measured as the last ask price prior to the block trade minus the last bid price before the block trade divided by the average of both prices. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey LM test statistics respectively. One EUA Futures contract has an underlying of 1000 EUAs.

\*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

Variables	Permanent effects		Total effects		Temporary effects	
	Purchases	Sales	Purchases	Sales	Purchases	Sales
<b>Size</b>	-8.11E-05 (0.0004)	<b>-0.0004***</b> (0.0001)	0.0002 (0.0001)	<b>-1.53E-04**</b> (6.15E-05)	-0.0002 (0.0004)	<b>-0.0002***</b> (8.19E-05)
<b>Volatility</b>	0.1280 (0.1256)	0.0825 (0.0353)	<b>-0.0977**</b> (0.0397)	<b>0.0877***</b> (0.0210)	<b>0.2775**</b> (0.1291)	-0.0060 (0.0280)
<b>Turnover</b>	<b>0.0003*</b> (0.0002)	<b>-7.42E-05*</b> (4.08E-05)	6.10E-05 (5.20E-05)	1.68E-05 (2.43E-05)	<b>0.0003*</b> (0.0002)	<b>-9.1E-05***</b> (3.23E-05)

<b>Marketreturn</b>	0.0075 (0.0098)	<b>0.0154***</b> (0.0025)	<b>-0.0262***</b> (0.0031)	<b>0.0101***</b> (0.0015)	<b>0.0336***</b> (0.0101)	<b>0.0052***</b> (0.0020)
<b>Momentum</b>	-0.0048 (0.0045)	-0.0015 (0.0012)	<b>-0.0044***</b> (0.0014)	<b>-0.0012*</b> (0.0007)	-0.0007 (0.0047)	-0.0002 (0.0010)
<b>BAS</b>	-0.1230 (0.0939)	<b>0.2152***</b> (0.0387)	<b>-0.1343***</b> (0.0297)	<b>0.1929***</b> (0.0230)	0.0271 (0.0965)	0.0203 (0.0307)
<b>Constant</b>	0.0010 (0.0018)	<b>0.0015***</b> (0.0005)	-0.0006 (0.0006)	<b>0.0008***</b> (0.0003)	0.0016 (0.0019)	<b>0.0007*</b> (0.0004)
<b>Observations</b>	<b>8356</b>	<b>8359</b>	<b>8356</b>	<b>8359</b>	<b>8356</b>	<b>8359</b>
<b>R-squared</b>	0.0008	0.0152	0.0169	0.0237	0.0023	0.0031
<b>BG-LM</b>	0.21	0.08	0.06	0.14	0.07	0.12
<b>BPG</b>	0.15	0.07	0.07	0.08	0.11	0.09

Results here point to clear differences in the effects of determinants of block trade impacts examined. Evidence that both buyer and seller initiated larger trades (block trades) on the ECX induce temporary and permanent price impacts is reported. Increased liquidity also generates larger price impacts. Although this is unusual, it is shown to be true in both cases of the liquidity variables included in the model. The dissimilarity in market properties between the EU-ETS hybrid cap and trade scheme and traditional financial markets is underscored by the differences in the impact of the two liquidity measures used in the model. The estimates of the volatility coefficients are unclear as to the distinctive impact of volatility on block trade price impact.

Further, evidence corroborates the prediction that there is reduced price impact for both purchase and sell block trades when an instrument is experiencing a price run-up leading to the block trade execution. For market returns, evidence in line with previous studies citing larger price impact for block purchases and smaller price impact for block sales is provided. Table 3.3 also shows that the highest  $R^2$  values are obtained for total effects regression estimates at 2.4% and 1.7% for sell and purchase block trades regressions respectively.

#### **3.4.4. Intraday Variations in Price Impact**

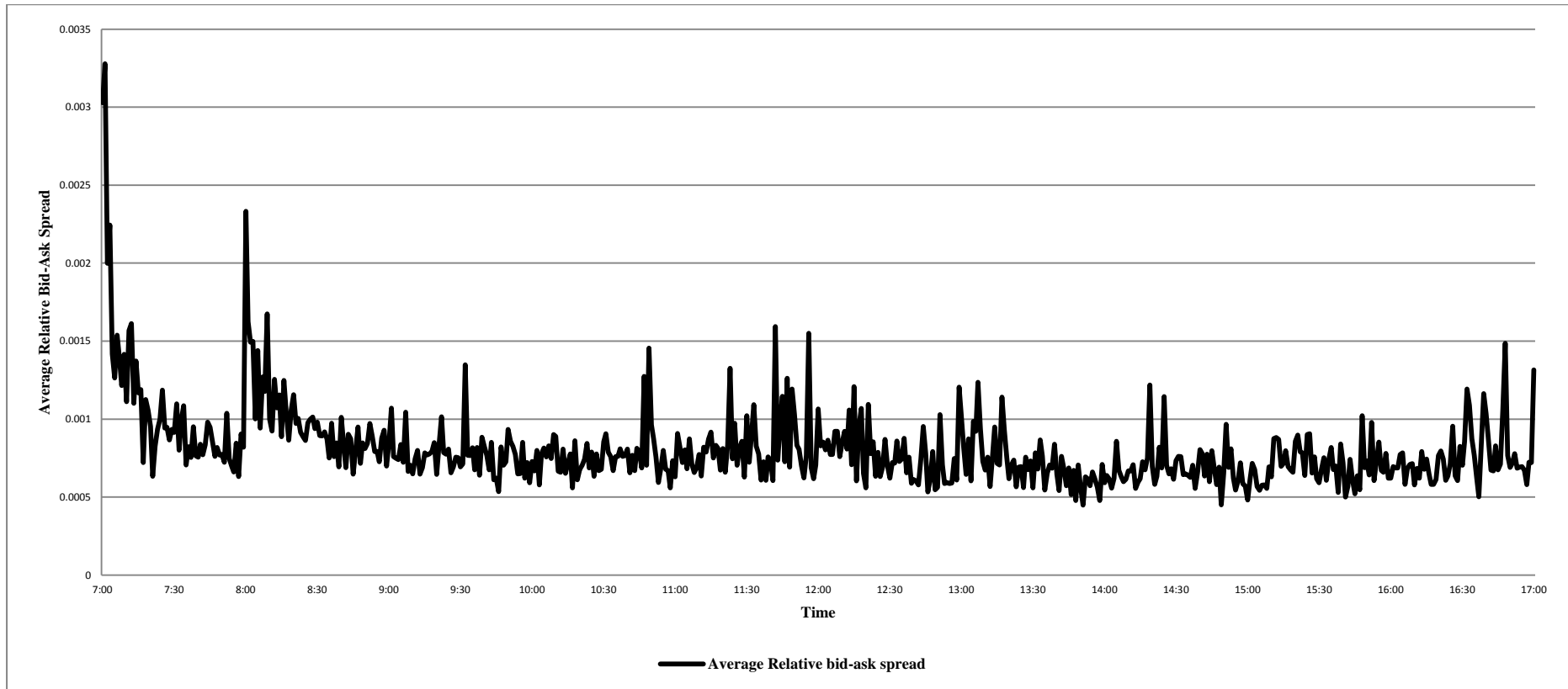
In traditional markets, spreads have been reported to conform to a U shaped pattern over the trading day. Little has been reported on intraday variations in the EU-ETS however. Rotfuß (2009) reports a roughly U shaped pattern of intraday volatility on the ECX using ECX data from first year of trading in Phase II. In chapter 2 however, report a slightly different intraday pattern of volatility (using standard deviation of half-hour returns) and traded volumes with 2009 data from the same platform. The authors show an inverted S shaped pattern for both trading activity measures. Indeed the pattern reported by Rotfuß (2009) is closely similar to the inverted S shaped pattern in the former's study. To this researcher's knowledge, the only available evidence of intraday variations in spread pattern available for the EU-ETS is the work of Ibikunle et al. (2012). The authors, using the Huang and Stoll (1997) spread decomposition model obtain half-spread estimates for six trading intervals on the ECX. The estimates suggest that spreads are highest during the opening two hours of the trading day and decreases throughout the trading day. The sixth interval is the after-hours trading period; the study shows a marked rise in the spread estimates during this interval. This shows a U

shaped pattern, lending credence to the reports of studies carried out on traditional trading platforms.

Figure 3.1 shows intraday variations in average relative bid-ask spread computed by using the entire dataset (including non-block trades). There is a discernible suggestion of a U shaped pattern emerging.

**Figure 3.1. Intraday Variations in Relative Bid-Ask Spread on the ECX**

The figure shows intraday relative bid-ask spread pattern for all trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. Average bid-ask spread which is defined for each trade as the last ask price prior to the trade minus the last bid price before the trade divided by the average of both prices is computed for each of the six EUA Futures contracts in our sample and then averaged cross-sectionally across all contracts.



In order to examine the presence of intraday variations in the intensity of block trade price impact for the ECX, the trading day is divided into three intervals in line with previous studies. The intervals are the first trading hour of the day (7:00-8:00 hours UK local time), the mid-trading day interval (08:01-16:00 hours UK local time) and the final trading interval is the final trading hour of the day (16:01-17:00 hours UK local time). For each interval, a dummy variable takes on the value of 1 if a block trade is executed during that interval and otherwise a value of 0 is allocated.  $TimeDum_1$  and  $TimeDum_2$  respectively stand for the first and second intervals and are shown in the equation (3.5) (other variables have been defined in section 3.3). The final trading interval is employed as the reference category and therefore is excluded from the actual regressions. The coefficient estimates obtained for the first two categories is representative of the price impact conduct in comparison to the reference category  $TimeDum_3$ :

$$Price\ Impact = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \beta_7 TD_1 + \beta_8 TD_2 + \varepsilon \quad (3.5)$$

Table 3.4 shows the results of equation (3.5) estimation for all, purchase and sell block trade categories using OLS and the Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix. The regression is estimated using all three price impact variables individually as dependent variables. For purchase and all block trades the  $TimeDum_2$  dummy variables are statistically significant for all price impact measures. Block trades executed during the first hour of the trading day encounter price impact which are not significantly different from those executed during the last hour of the day. For purchase trades, there are significant differences between trades executed during the middle of the day and those executed in the last hour of the normal trading day, the coefficient estimates however suggest that the greater price impact generally occurs during the middle interval of the trading day. This holds true for total and permanent effects estimates, there is however a marginal difference in the coefficients for temporary effects estimates suggesting comparable levels of price impact for the first hour and the middle of the day. For all block trades combined, the inclination holds for only temporary effects estimates; however, the  $TimeDum_1$  coefficients are statistically insignificant. Most of the sell block trade coefficient estimates show that sell block trades during the first two intervals do not induce price impact significantly different from those prompted by trades in the last hour of the trading day. The permanent effects  $TimeDum_2$  coefficient is significant at 10% level. The estimate suggests

that for sell block trades, trades executed during the middle of the trading day induce higher price impact than those during the first hour of trading day. The differences in the effect of intraday trading activity patterns on the ECX and other traditional financial platforms may contribute to this behaviour. For a number of studies, the first hour of the trading has been reported as the period when block trades induce the largest price impact (see Frino et al., 2007 as an example). Earlier in this section, it is reported that wider spreads in fact characterise less price impact on the ECX contrary to earlier studies, this result is therefore the only logical outcome of the investigation of time of day effect. This is because, Figure 3.1 shows that the lowest spreads are experienced during the middle of the day and the highest spread intervals are more likely during the first hour of the trading day.

**Table 3.4 Determinants of Price Impact and Time of Day Effects**

The table reports regression results for all, buyer and seller initiated block trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. The coefficients are reported along with the standard errors (in parenthesis). The following regression controlling for time of day effect is estimated using OLS and also with Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$PriceImpact = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \beta_7 TD_1 + \beta_8 TD_2 + \varepsilon$$

where Price Impact corresponds to permanent, total and temporary price impacts. Size represents the natural logarithm of the number of December maturity futures contracts for each block trade; Volatility is the standard deviation of trade to trade returns prior to the block trade on the trading day; Turnover is the natural logarithm of the futures contracts turnover on the trading day prior to the block trade, turnover is calculation as a ratio of total trade volume prior to the block to the prevailing open interest estimates; Marketreturn is the return of EUA Futures contract specific index computed by the ECX; Momentum corresponds to the cumulative return on the specific EUA Futures contract in the five days prior to the block trade; BAS is the prevailing relative bid-ask spread at the time the block trade is executed, BAS is measured as the last ask price prior to the block trade minus the last bid price before the block trade divided by the average of both prices. TimeDum<sub>1</sub> equals 1 if the block trade occurs in the first hour of the trading day and 0 otherwise, TimeDum<sub>2</sub> takes the value of 1 if the trade occurs between 8:00hours and 16:00hours London local time. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey LM test statistics respectively. One EUA Futures contract has an underlying of 1000 EUAs. \*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

Variables	Permanent effects			Total effects			Temporary effects		
	All	Purchase	Sell	All	Purchase	Sell	All	Purchase	Sell
<b>Size</b>	-2.12E-04 (0.0002)	-7.12E-05 (0.0004)	<b>-0.0004***</b> (0.0001)	-1.56E-05 (7.1E-05)	0.0002 (0.0001)	<b>-0.0002**</b> (6.16E-05)	-1.93E-04 (0.0002)	-0.0002 (0.0004)	<b>-0.0002***</b> (8.20E-05)
<b>Volatility</b>	<b>0.1297*</b> (0.0679)	0.1405 (0.125857)	<b>0.0815**</b> (0.0353)	0.0130 (0.0233)	<b>-0.1014**</b> (0.0397)	<b>0.0881***</b> (0.0210)	<b>0.1435**</b> (0.0688)	<b>0.2940**</b> (0.1293)	-0.0074 (0.0280)
<b>Turnover</b>	<b>0.0002*</b> (9.09E-05)	<b>0.0004**</b> (0.000178)	<b>-7.61E-05*</b> (4.42E-05)	1.89E-05 (3.1E-05)	2.87E-05 (5.6E-05)	2.78E-05 (2.63E-05)	<b>0.0002*</b> (9.22E-05)	<b>0.0004**</b> (0.0002)	<b>-0.0001***</b> (3.50E-05)
<b>Market Return</b>	<b>0.0140***</b> (0.0051)	0.0071 (0.00979)	<b>0.0153***</b> (0.0025)	<b>-0.006***</b> (0.0017)	<b>-0.026***</b> (0.0031)	<b>0.0100***</b> (0.0015)	<b>0.0196***</b> (0.0052)	<b>0.0339***</b> (0.0101)	<b>0.0053***</b> (0.0020)
<b>Momentum</b>	-0.0034	-0.0052	-0.0015	<b>-0.0030***</b>	<b>-0.004***</b>	<b>-0.0013*</b>	-0.0009	-0.0012	-0.0002



	(0.0024)	(0.0045)	(0.0012)	(0.0008)	(0.0014)	(0.0007)	(0.0024)	(0.0047)	(0.0010)
<b>BAS</b>	-0.0316 (0.0584)	-0.1128 (0.0939)	<b>0.2151***</b> (0.0387)	<b>-0.0530***</b> (0.0200)	<b>-0.137***</b> (0.0297)	<b>0.1936***</b> (0.0230)	0.0328 (0.0593)	0.0403 (0.0965)	0.0196 (0.0307)
<b>TimeDum<sub>1</sub></b>	0.0007 (0.0005)	0.0012 (0.0010)	5.32E-05 (0.0003)	3.77E-05 (0.0002)	-0.0004 (0.0003)	0.0002 (0.0002)	0.0007 (0.0005)	0.0016 (0.0010)	-1.62E-04 (0.0002)
<b>TimeDum<sub>2</sub></b>	<b>0.0006**</b> (0.0003)	<b>0.0012***</b> (0.0005)	<b>-0.0002*</b> (0.0001)	<b>-0.0002**</b> (8.50E-05)	<b>-0.0004**</b> (0.0002)	-8.36E-05 (7.29E-05)	<b>0.0008***</b> (0.0003)	<b>0.0016***</b> (0.0005)	-0.0001 (9.72E-05)
<b>Constant</b>	0.0090 (0.0010)	0.0004 (0.0018)	<b>0.0017***</b> (0.0005)	0.0003 (0.0003)	-0.0004 (0.0058)	<b>0.0009***</b> (0.0003)	0.0006 (0.0010)	0.0008 (0.0019)	<b>0.0007**</b> (0.0003)
<b>Observations</b>	<b>16715</b>	<b>8356</b>	<b>8359</b>	<b>16715</b>	<b>8356</b>	<b>8359</b>	<b>16715</b>	<b>8356</b>	<b>8359</b>
<b>R-squared</b>	0.0011	0.0017	0.0156	0.0029	0.0176	0.0245	0.0020	0.0037	0.0033
<b>BG-LM</b>	0.18	0.22	0.09	0.14	0.07	0.13	0.10	0.09	0.12
<b>BPG</b>	0.11	0.15	0.08	0.18	0.08	0.08	0.28	0.11	0.10

### **3.4.5. Trade Size Dependencies on Price Impact**

Microstructure studies suggest that liquidity influenced trades are usually characterised by small orders while informed trades usually have larger orders (see Glosten and Harris, 1988 as an example). Analyses of the large orders dominated after hours trading market on the ECX in chapter 2 indicate that this proposition may be valid in the European carbon market. If different types of trades are characterised by differing trades sizes, it is suspected that block trades will not uniformly cause price impact. Price impact as an important function of trade size has already been demonstrated in this thesis. To determine how block trades of different sizes can affect price functioning, the approach of Alzahrani et al. (2010) and Madhavan and Cheng (1997) in dividing block trades in the sample into three different trade size categories is adopted. Block trades are divided into three groups as follows: 50-100 contracts, 101-200 contracts, and more than 200 contracts. Equation (3.5) is estimated for each of the groups using all three measures of price impact already identified.

**Table 3.5 Determinants of Price Impact and Block Trade Sizes (Purchases)**

The table reports regression results for buyer initiated block trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. The coefficients are reported along with the standard errors (in parenthesis). The following regression controlling for time of day effect is estimated using OLS and also with Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$Price\ Impact = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \beta_7 TD_1 + \beta_8 TD_2 + \varepsilon$$

where Price Impact corresponds to permanent, total and temporary price impacts. Size represents the natural logarithm of the number of December maturity futures contracts for each block trade; Volatility is the standard deviation of trade to trade returns prior to the block trade on the trading day; Turnover is the natural logarithm of the futures contracts turnover on the trading day prior to the block trade, turnover is calculation as a ratio of total trade volume prior to the block to the prevailing open interest estimates; Marketreturn is the return of EUA Futures contract specific index computed by the ECX; Momentum corresponds to the cumulative return on the specific EUA Futures contract in the five days prior to the block trade; BAS is the prevailing relative bid-ask spread at the time the block trade is executed, BAS is measured as the last ask price prior to the block trade minus the last bid price before the block trade divided by the average of both prices. TimeDum<sub>1</sub> equals 1 if the block trade occurs in the first hour of the trading day and 0 otherwise, TimeDum<sub>2</sub> takes the value of 1 if the trade occurs between 8:00hours and 16:00hours London local time. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey LM test statistics respectively. One EUA Futures contract has an underlying of 1000 EUAs.

\*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

	Permanent effects			Total effects			Temporary effects		
	50-100	101-200	>200	50-100	101-200	>200 (3.45%)	50-100	101-200	>200
% Proportion	(89.92%)	(6.63%)	(3.45%)	(89.92%)	(6.63%)		(89.92%)	(6.63%)	(3.45%)
<b>Variables</b>									
<b>Size</b>	0.0005 (0.0006)	0.0042 (0.0091)	0.0006 (0.0006)	-0.0002 (0.0002)	0.0001 (0.0012)	-0.0002 (0.0008)	0.0007 (0.0006)	0.0041 (0.0092)	0.0008 (0.0009)
<b>Volatility</b>	0.1082 (0.1030)	0.5860 (1.3036)	-0.1827 (0.1463)	<b>-0.2042***</b> (0.0414)	<b>1.3637***</b> (0.1728)	<b>-0.4455**</b> (0.1783)	<b>0.3632***</b> (0.1073)	-0.6891 (1.3141)	0.2829 (0.2119)
<b>Turnover</b>	<b>0.0005***</b> (0.0002)	-0.0040 (0.0019)	-0.0003 (0.0002)	2.34E-06 (5.82E-05)	0.0004 (0.0003)	0.0002 (0.0003)	<b>0.0005***</b> (0.0002)	-0.0007 (0.0019)	-0.0004 (0.0003)
<b>Market</b>	<b>0.0155*</b> (0.0080)	-0.141 (0.1091)	0.0077 (0.0120)	<b>-0.0225***</b> (0.0032)	<b>-0.0722***</b> (0.0145)	-0.0125 (0.0146)	<b>0.0382***</b> (0.0083)	-0.0715 (0.1099)	0.0195 (0.0174)

<b>Momentum</b>	<b>-0.0060*</b> (0.0037)	-0.0032 (0.0499)	-0.0030 (0.0060)	<b>-0.0068***</b> (0.0015)	<b>0.0375***</b> (0.0066)	<b>-0.0239***</b> (0.0073)	0.0004 (0.0038)	-0.0388 (0.0503)	<b>0.0199**</b> (0.0087)
<b>BAS</b>	-0.0936 (0.0742)	-0.7974 (1.4539)	-0.2368 (0.2314)	<b>-0.1146***</b> (0.0299)	<b>-0.4928**</b> (0.1927)	-0.0351 (0.2820)	0.0382 (0.0773)	-0.3243 (1.4656)	-0.2096 (0.3351)
<b>TimeDum<sub>1</sub></b>	-0.0008 (0.0008)	0.0079 (0.0123)	0.0005 (0.0019)	-0.0004 (0.0003)	-0.0008 (0.0016)	<b>0.0047**</b> (0.0024)	0.0012 (0.0008)	0.0087 (0.0124)	-0.0042 (0.0028)
<b>TimeDum<sub>2</sub></b>	<b>0.0006*</b> (0.0004)	<b>0.0090*</b> (0.0048)	<b>0.0013**</b> (0.0006)	<b>-0.0004**</b> (0.0002)	-0.0003 (0.0006)	<b>0.0013*</b> (0.0007)	<b>0.0012***</b> (0.0004)	<b>0.0092**</b> (0.0048)	8.41E-05 (0.0008)
<b>Constant</b>	-0.0008 (0.0024)	-0.0317 (0.0457)	-0.0055 (0.0038)	0.0013 (0.0009)	-0.0006 (0.0060)	0.0014 (0.0046)	-0.0021 (0.0025)	-0.0314 (0.0461)	-0.0069 (0.0055)
<b>Observations</b>	<b>7514</b>	<b>554</b>	<b>288</b>	<b>7514</b>	<b>554</b>	<b>288</b>	<b>7514</b>	<b>554</b>	<b>288</b>
<b>R-squared</b>	0.0029	0.0123	0.0480	0.0212	0.1932	0.0950	0.0069	0.0112	0.0517
<b>BG-LM</b>	0.02	0.94	0.09	0.03	0.20	0.10	0.02	0.94	0.06
<b>BPG</b>	0.03	0.66	0.07	0.01	0.06	0.03	0.03	0.66	0.10

Table 3.5 reports the results for purchase block trades. The first observation made is the very high proportion of the lower end block trades. Approximately 90% of executed trades in the sample are for the smallest trade size category (50-100 EUA Futures contracts). Another observation is the dearth of estimates significantly different from zero. What this implies is that though there may be variations in the range of price impact induced by block trades of different sizes (as evidenced by coefficient estimates), these variations are not significant.

For Market return, the total effects estimates are statistically significant for the first two categories. Negative market return estimates for all three categories of trade sizes indicate lower price impact for purchase block trades across all examined trade sizes. The coefficient estimates for the 101-200 contracts category is nearly a third smaller than that of the smallest size category, suggesting in effect that price impact diminishes by a third with larger orders. The Marketreturn estimates for the largest category are insignificant. The negative and significant bid-ask spread estimates indicate lower price impact with increasing trade sizes as well. The negative estimates for market return are consistent with results obtained for total effects of purchase block trades in Tables 3.3 and 3.4. Temporary and permanent Marketreturn estimates for the smallest sized category of trades (50-100 contracts) are however positive and statistically significant at 1% and 10% levels respectively. They imply larger price impact for purchase block trades of size 50-100 EUA futures contracts especially for temporary effects. The temporary effects coefficient is more than two and half times the value of the permanent effects coefficient indicating that most of the price impact determined by Marketreturn is temporary. This result is consistent with temporary effects estimates of purchase block trades in Tables 3.3 and 3.4. This is expected since the 50-100 contracts category account for nearly 90% of the trades in the sample.

It is also observed that larger sized block trades especially the 101-200 contracts category potentially induce higher price impact than smaller sized ones. As an example, for the size (volume) variable, it can be seen that for each of permanent, temporary and total effects, the 101-200 contracts size range have positive coefficients that are larger than the other two groups. The positive values indicate a positive relationship with price impact across all three effects. For volatility, which measures the dispersion of participants' belief, the total effects estimates for all three trade sizes are statistically significant. Coefficient of the mid-range sized block trades is positive and statistically significant at 1% level and higher than the other groups with coefficient of more than one reported (1.364). This means for this group,

increasing volatility is associated with higher price impact. The negative and statistically significant coefficients for the lowest and largest volume size categories imply that increased volatility does not necessarily imply higher price impact, it instead signals the opposite. This is consistent with earlier total effects coefficient estimates for purchase block trades from Tables 3.3 and 3.4. And since these two trades groups account for more than 93% of the sample size, the consistency with earlier results on purchase trades is not surprising. The total effects coefficient estimates for momentum are statistically significant for all three categories; again the results suggest that the middle group induce higher price impact on a price run-up while the other two categories agree with the argument of Saar (2001). The negative and statistically significant coefficients suggest that less price impact is induced on a price run up.

The trend where the middle category shows estimates higher than the other two categories is also reported for the time of day dummy variables. The permanent effects estimates for  $\text{TimeDum}_2$  are positive and statistically significant and they show the 101-200 contracts category having a coefficient of 0.00898, which is more than seven times the value of the closest estimate (>200 contracts). The permanent effects time dummy variables also lends credence to the earlier suggestion in Table 3.4 that purchase block trades executed in the middle of the day marginally induce larger price impact than those executed in the first hour of the trading day. Most of the  $\text{TimeDum}_2$  estimates are statistically significant and corroborate the earlier findings; the only exception is the total effects estimate for the largest trade size category. The  $\text{TimeDum}_1$  estimate at 0.0047 (statistically significant at 5% level) is more than three times the value of the  $\text{TimeDum}_2$  estimate (0.00126) which is significant at 10% level. This is the only indication that the largest trades' size group may encounter higher price impact during the first hour of trading than during the middle of the day. An explanation of this deviation is attempted further down in this section.

Differentiation and in some cases, dominance, in terms of price impact, of the block size category of 101-200 contracts from (over) the largest size contracts category is unexpected. The interesting pattern evolving may be an indication of the 101-200 contracts category becoming the starting point of price impact effects. Already presented are estimates indicating that the 50-100 group trades induce more temporary price impact than permanent price impact, suggesting most of the trades in this group are liquidity seeking transactions. This coupled with the large volume of block trades of 50 contracts trade sizes suggest a

gradual erosion of the market's view of 50 contracts as a block trade. The ECX sets the standard for what is regarded as block trade and currently it stands at 50 contracts according to exchange rules. Markets have however been known to induce structural shifts in response to emerging trading culture. The ECX as an EU-ETS platform, although a market entity, is a product of political action and may not be subject to the same expectations as regular markets developed as engines of wealth creation. Even then, the market seems to be taking a life of its own gradually. This however does not explain why the largest contract size category shows less price impact effects than the middle size category. Results from Barclay and Warner's (1993) analysis of transactions data from a sample of NYSE firm may provide credible insight. Barclay and Warner (1993) argue that under certain conditions, informed traders, rather than trade in large sizes, would usually split up their trades into smaller chunks falling into the medium sized category, hence the asymmetric phenomenon. Further, the frequency of on-screen buyer initiated block trades >200 contracts on the ECX (3.45%) over three years and four months is very low. The low frequency levels may be a contributing factor to the low coefficient estimates. Perhaps infrequent trade sizes are likely to elicit less price reaction than those that are fairly regular.

There is also a possible explanation for why the >200 category is associated with the largest price impact during the first hour of the trading day (which is inconsistent with other results in this section). More than 98% of the >200 block trades occur outside of the first hour of normal trading day. Total effects coefficient for the >200 contracts category indicates that greater price impact occurs during the first hour of the trading day for this group of trades. Therefore, since trades during the other periods in the day are less likely to induce price impact in comparison to those executed during the first hour, the effects of the >200 contracts category block trades may have been consequently muted by general reduced price reaction to >200 trades during these periods of the normal trading day.

The  $R^2$  values for the equation estimations range from 2.13% to 19.32% for total effects estimates which is an indication of the significant explanatory power of the model.

**Table 3.6 Determinants of Price Impact and Block Trade Sizes (Sales)**

The table reports regression results for buyer initiated block trades of December maturity EUA Futures contracts executed on the European Climate Exchange (ECX) platform between January 2008 and April 2011. The coefficients are reported along with the standard errors (in parenthesis). The following regression controlling for time of day effect is estimated using OLS and also with Newey and West (1987) heteroscedastic and autocorrelation consistent covariance matrix:

$$Price\ Impact = \alpha + \beta_1 \ln(SZ) + \beta_2 SD + \beta_3 \ln(TO) + \beta_4 MR + \beta_5 MO + \beta_6 BAS + \beta_7 TD_1 + \beta_8 TD_2 + \varepsilon$$

where Price Impact corresponds to permanent, total and temporary price impacts. Size represents the natural logarithm of the number of December maturity futures contracts for each block trade; Volatility is the standard deviation of trade to trade returns prior to the block trade on the trading day; Turnover is the natural logarithm of the futures contracts turnover on the trading day prior to the block trade, turnover is calculation as a ratio of total trade volume prior to the block to the prevailing open interest estimates; Marketreturn is the return of EUA Futures contract specific index computed by the ECX; Momentum corresponds to the cumulative return on the specific EUA Futures contract in the five days prior to the block trade; BAS is the prevailing relative bid-ask spread at the time the block trade is executed, BAS is measured as the last ask price prior to the block trade minus the last bid price before the block trade divided by the average of both prices. TimeDum<sub>1</sub> equals 1 if the block trade occurs in the first hour of the trading day and 0 otherwise, TimeDum<sub>2</sub> takes the value of 1 if the trade occurs between 8:00hours and 16:00hours London local time. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey LM test statistics respectively. One EUA Futures contract has an underlying of 1000 EUAs.

\*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

Variables	Permanent effects			Total effects			Temporary effects		
	50-100 (90.85%)	101-200 (5.91%)	>200 (3.24%)	50-100 (90.85%)	101-200 (5.91%)	>200 (3.24%)	50-100 (90.85%)	101-200 (5.91%)	>200 (3.24%)
<b>Size</b>	<b>-0.0006***</b> (0.0002)	0.0002 (0.0007)	6.11E-06 (0.0006)	<b>-0.0003***</b> (0.0001)	-6.93E-05 (0.0004)	-0.0003 (0.0004)	<b>-0.0003**</b> (0.0002)	0.0003 (0.0006)	0.0003 (0.0004)
<b>Volatility</b>	<b>0.0724**</b> (0.0373)	0.1494 (0.1347)	0.2191 (0.1971)	<b>0.0790***</b> (0.0221)	<b>0.3850***</b> (0.0789)	<b>-0.3131**</b> (0.1299)	-0.0075 (0.0296)	<b>-0.2344**</b> (0.0989)	<b>0.5352***</b> (0.1491)
<b>Turnover</b>	<b>-8.22E-05*</b> (4.75E-05)	-0.0002 (0.0001)	<b>0.0003*</b> (0.0002)	3.52E-05 (2.81E-05)	<b>-1.6E-04*</b> (8.35E-05)	0.0001 (0.0001)	<b>-1.2E-04***</b> (3.78E-05)	4.16E-05 (0.0001)	0.0002 (0.0001)
<b>Market Return</b>	<b>0.0157***</b> (0.0027)	0.0143 (0.0089)	0.0058 (0.0100)	<b>0.0098***</b> (0.0016)	0.0061 (0.0052)	<b>0.0210***</b> (0.0066)	<b>0.0060***</b> (0.0022)	0.0082 (0.0065)	<b>-0.0153**</b> (0.0076)



<b>Momentum</b>	-0.0011 (0.0013)	-0.0025 (0.0043)	<b>-0.0120**</b> (0.0056)	-0.0011 (0.0008)	0.0008 (0.0025)	<b>-0.0080**</b> (0.0037)	3.47E-05 (0.0010)	-0.0033 (0.0032)	-0.0041 (0.0043)
<b>BAS</b>	<b>0.2424***</b> (0.0411)	<b>-0.386***</b> (0.1452)	<b>0.3094*</b> (0.1621)	<b>0.2246***</b> (0.0244)	<b>-0.353***</b> (0.0851)	<b>0.2218**</b> (0.1069)	0.0156 (0.0327)	-0.0340 (0.1066)	0.0885 (0.1226)
<b>TimeDum<sub>1</sub></b>	1.23E-05 (0.0003)	0.0004 (0.0009)	-0.0009 (0.0012)	0.0002 (0.0002)	-1.71E-05 (0.0005)	-0.0012 (0.0008)	-0.0002 (0.0002)	0.0004 (0.0007)	0.0004 (0.0009)
<b>TimeDum<sub>2</sub></b>	<b>-0.0003**</b> (0.0001)	0.0002 (0.0004)	<b>0.0009**</b> (0.0004)	-1.16E-04 (7.82E-05)	6.44E-05 (0.0002)	0.0002 (0.0003)	-0.0002 (0.0001)	0.0001 (0.0003)	<b>0.0008**</b> (0.0004)
<b>Constant</b>	<b>0.0027***</b> (0.0008)	-0.0019 (0.0038)	0.0003 (0.0033)	<b>0.0015***</b> (0.0005)	-0.0004 (0.0022)	0.0025 (0.0022)	<b>0.0012**</b> (0.0006)	-0.0015 (0.0028)	-0.0022 (0.0025)
<b>Observations</b>	<b>7594</b>	<b>494</b>	<b>271</b>	<b>7594</b>	<b>494</b>	<b>271</b>	<b>7594</b>	<b>494</b>	<b>271</b>
<b>R-squared</b>	0.0169	0.0281	0.0669	0.0275	0.0874	0.1052	0.0035	0.0205	0.1046
<b>BG-LM</b>	0.00	0.36	0.40	0.00	0.64	0.43	0.00	0.27	0.07
<b>BPG</b>	0.02	0.09	0.10	0.01	0.10	0.09	0.06	0.21	0.06

Table 3.6 shows the results for sell block trades. A trade size distribution trend similar to Table 3.5 is observed, with approximately 91% of executed trades in the sample made up of the smallest trade size category (50-100 EUA contracts). Also, as in the purchase block trades estimates; there is a dearth of coefficients significantly different from zero.

The total effects coefficient estimates for the volatility variable are all very significant. The negative and statistically significant value of the >200 contracts category shows that increased volatility results in higher price impact for sell trades of 200 contracts or more on the ECX. The opposite is the case for smaller sized trades. Size shows a positive relationship with price impact as evidenced by the negative total effects coefficient estimates. Consistent with Alzahrani et al. (2010), the statistically significant coefficient for the lowest sized contract groups is larger than the two other groups indicating that smaller sized sell block trades are more informative than larger ones. Professional traders have long been known to split large block trades into smaller trades to avoid early detection of the information content of the trades (see Barclay and Warner, 1993; Chakravarty, 2001). Although microstructure studies show that informed trades are discernible also from the direction and frequency of trades, trades fragmentation potentially mutes the price impact of block trades (Keim and Madhavan, 1996). Market return coefficient estimates for total effects are all positive and estimates for the smallest and largest groups are statistically significant at 1% level. The trend shown by the Market return coefficients is consistent with that of size coefficients; there is larger price impact for the smaller sized trades as they are perceived as being more informative.

For the >200 contracts category, the total effects and permanent effects coefficient estimates for the momentum variable is negative and statistically significant at 5% level indicating that there is indeed higher price impact on a price run-up contrary to the effect for purchases. This validates the sell coefficient estimates in Tables 3.3 and 3.4 as well as the submission of Frino et al. (2007). Viewed in tandem with the block purchase estimates in previous tables, it can be submitted that block purchase trades behaviour on the ECX are consistent with Saar (2001) and sell block trades with Frino et al. (2007). The difference in behavioural patterns for trades on the same platform is quite interesting.

The BAS estimates are all statistically significant for both permanent and total effects. There is an interesting scenario playing out with both effects' estimates however. Only the 101-200 contracts category has negative coefficients which is consistent with Frino et al. (2007), the other two categories are positive, reinforcing the suggestions made on account of Tables 3.3 and 3.4 that on the ECX, widening of the spreads are linked with reducing price impact. As explained earlier in this section, the negative coefficients of the middle group which is in keeping with previous studies' results represents an asymmetric relationship among the different trade sizes. This norm may not be unconnected with a structural shift in the market's definition of block trade. The dummy variable coefficients are largely statistically insignificant and hence very little inferences can be drawn from them.

The  $R^2$  values for total effects estimates are 2.75%, 8.74% and 10.52% respectively for the smallest sized to the largest sized sell block trade categories. Temporary effects are 0.4%, 2.05% and 10.46%. And permanent effects values are 1.6%, 2.80% and 6.69% respectively.

The general pattern exhibited in Table 3.6 suggests that sell block trades executed on the ECX on the whole are less likely to induce price impact than purchase block trades.

### **3.5. Conclusion**

It is important to state that a significant proportion of the results in this study contradict the literature for equity markets, the reasons for this are argued with empirical evidence. Further, it may seem quite difficult to reconcile some of the results. This is due to the low level of block trade price impact (which contributes to lack of statistical significance for a number of the coefficients) already reported in the chapter. This issue is discussed independently for each section of the analysis in good detail with links to literature as appropriate.

In this chapter, the determinants of price impact for block trades executed on the world's largest carbon trading platform are examined by analysing tick data on 16,715

block trades over a three year period. While price impact of block trades has been considerably studied in traditional international markets, there has been no study carried out on what determines price impact of block trades in permit markets. Block trades increasingly constitute large Euro volumes of trades in the EU-ETS as more installations try to avoid counter-party risks by trading on platforms rather than OTC.

Empirical analysis is undertaken by estimating regression models used to determine price impact of block trades in previous market microstructure studies on traditional equity markets. The analyses are conducted on all block trades in the sample and for block purchases and sales separately in order to investigate the possibility of price impact asymmetry in the carbon markets. Results show that most of the block trades on the ECX occur at the minimum quantity for the exchange sanctioned block trade size of 50 contracts. This is consistent for both buyer and seller initiated block trades. This indicates that traders on either side of block trades on the ECX employ identical trading tactics for order placement. The evidence shows that stealth trading may be a trading strategy of choice for most block traders on the platform. The low volume of block trades of 16,715 (1.74%) out of a total of 961,131 trades also suggest that block trades may be commonly split into quantities below the block trade threshold. This suggestion is reinforced by the nature of the EU-ETS, where most participants are either big compliance traders or institutional investors.

In comparison with customary instruments, the price impact of carbon futures on the ECX is small and largely statistically insignificant. Lack of price reaction to large trades can be viewed as a possible consequence of thin trading (see Ball and Finn, 1989). Although trading has advanced in the EU-ETS, this is still very low in comparison to established markets. Since there is little price reaction, there is very little opportunity of benefitting from price impact asymmetry before and after block trades. Some evidence of price impact asymmetry for buyer and seller initiated block trades is found. For sell trades the permanent effect is 0.00153 and 0.000949 for purchases. The purchase trade estimate borders on significance while the sell trade estimate is highly significant at 1% level. The result suggests higher premium is paid by sellers rather than buyers, which is a clear contradiction with many studies. It is not surprising that premium is paid on the ECX by sellers rather than buyers when the market structure is considered. The ECX is a derivatives exchange for emission

permits which are required for submission only once a year; hence for most trading days the permits are largely hedging instruments. Compliance buyers do not need to hold on to the underlying instruments all year round and therefore only need to take long positions in the market to ensure they are insulated against penalties for non-compliance. In the event that they are in possession of excess instruments, they can undertake a short position. Considering the fact that the permits hold little value to a compliance trader unless it is being submitted, many will willingly make concessions to sell them.

This chapter also provides evidence that lower price impact is characterised by wider spreads. For buyer initiated block orders, trade execution induces larger price impact in the ECX during the middle of the trading day than during the first and last trading hours. This chapter also affirms the fact that positive price run-up is associated with both lower price impact and higher price impact depending trade sign. For block purchases, there is smaller price impact when a trade occurs after a price run-up, while for block sales, there is greater price impact. There is however also a block trade size dependency to this.

The recent enactment of emissions trading legislation in Australia, the country with the highest per capita emission levels, once again underscores the growing significance of carbon emissions trading. Australia's ETS will become the second largest in the world when it comes online in 2015. Along with the EU-ETS and the New Zealand ETS, a platform for inter-regional emissions' trading is being set, therefore continued focus must be placed on the evolution of emissions markets. The results in this chapter shed some more light on several microstructure issues relating to block trading on the ECX, for instance there is evidence of sophisticated trading techniques now in play in the market. It is shown that in many cases, the most information laden trades are not the largest ones, but the medium (for most buys) and the small trades (for most sells); these seem to be the trades that move prices. Policy makers must therefore ensure that regulations in the emissions markets keep pace with trading innovations.

## **4. Carbon Futures Liquidity Effects in Phase II**

### **4.1. Introduction**

Butzengeiger et al. (2001) identify liquidity as a precondition for the success of an emissions trading scheme. The scheme should involve a sufficient pool of participants to ensure adequate volume of transactions on a regular basis; this results in the emergence of an explicit price signal to the market. Fragmentation of platforms can inhibit advancement of liquidity especially in nascent markets like the global carbon market; potentially, liquidity risk resulting from fragmentation of trading platforms is a risk in the EU-ETS as evidenced by low trading volumes in Phase I (see Hill et al., 2008). Liquidity is one of the most vital features investors search for in any financial market before trading. Financial market participants usually view a market as liquid if it is possible to transact in the market's instruments with reasonable speed, irrespective of the volume and size of transactions, and with little or no price impact on the security. Liquid securities trading therefore have low transaction costs, ease of transactions' settlement and virtually no asymmetric information costs (Sarr and Lybek, 2002). For new markets, low transaction costs are vital for advancement of trading volumes, which are necessary for efficient price discovery (see chapter 2) Given this importance of liquidity to the success of the EU-ETS and perhaps the establishment of a global cap and trade scheme; this thesis now investigates the liquidity effects on specific contracts on the EEX (one of the lowest volume platforms in Phase I of the EU-ETS) using four key events.

Liquidity cannot be directly inferred from improvement in transaction volumes in financial markets. Recent empirical contributions have shown that improvements in trading volumes are not necessarily associated with enhanced liquidity. Indeed volume and liquidity are weakly related over time (Johnson, 2008). Early studies on the subject of the relatedness of market liquidity and volume include the studies of Foster and Viswanathan (1993) and Lee et al. (1993) both of which show negative correlations. More recently, the use of Dow-Jones 30 industrial stocks and other instruments evidence only insignificant changes in bid-ask spread in relation to turnover (see Jones, 2002; Fujimoto, 2004). Danielsson and Payne (2010) using order

entry rates and depth measures as proxies for liquidity also find a negative correlation between trade volumes and liquidity.

In Phase I of the EU-ETS, there was over-allocation of carbon permits and restrictive regulations also contributed to a largely illiquid market. It can be argued that part of the problem with market quality during the phase is the fact that, Phase I was just a trial phase. Indeed, events during the phase gave indications of what could go wrong during the subsequent phases, especially the Phase II which is the legal Kyoto commitment period. In response to this and by earlier design intentions, there are regulatory changes between Phase I and Phase II (see Table 1.1 in chapter 1 for an outline). Tighter caps have also been introduced. If the implementation of new regulations and tighter caps for Phase II has been successful in reducing the over allocation of carbon allowances and improving market quality, one would expect a significant increase in market liquidity in the EU-ETS over time. I argue in the introduction to this thesis that the two main market functions are price discovery and liquidity and that these two give indication of market quality as well as market efficiency. This chapter therefore investigates whether or not there have been significant improvements in market liquidity since the start of trading in the Phase II. The investigations are carried out using the trading data for Dec-2008 carbon futures contract, which accounts for more than 70% of traded volumes on the EEX during the period in question. The Dec-2008 contract started trading in Phase I and its underlying also issued in Phase I, it can however only be submitted for compliance only towards Phase II emissions. The study is extended by also examining the liquidity effects of emissions verification results (for 2007 and 2008 compliance years) and introduction of European Commission Regulation (EC) No 994/2008 of 8 October 2008.

The EEX platform is chosen because this study investigates liquidity improvements. The carbon trading division of the EEX was clearly one of the illiquid platforms during the trial phase. During the early stages of Phase I, there were no trades for significant periods and trading spreads were large. As pointed out by Montagnoli and de Vries (2010), the trading volume on most EU-ETS platforms were thin in Phase I. Significant improvements in liquidity right from the start of Phase II can therefore be readily evidenced on the EEX than on the vastly liquid European Climate Exchange

(ECX). The low trading volumes on the EEX provide a significant advantage for capturing liquidity effects with the analytical methods used (see Hedge and McDermott, 2003). Further, among the largely illiquid platforms, it is the only one with accessible microstructure data variables required for this study.

Extant literature on the liquidity of the EU-ETS is scarce, to this researcher's knowledge, there is only one published paper by Frino et al. (2010) with direct focus on market liquidity. The study finds that liquidity improves over time for the EU-ETS. However, their results are not focused on analyzing liquidity effects of the onset of trading in Phase II and other events tested in this thesis, given that they only focus on quarterly results. This chapter provides daily review of volume and liquidity changes over shorter windows and with respect to evolution of transaction volumes. A further unpublished manuscript by Benz and Klar (2008) (earlier reviewed in the introduction section) looks at liquidity in Phase I of the scheme. These papers are not directly relevant to this study, given that its focus is on the liquidity changes between Phase I and Phase II of the EU-ETS and other events not previously examined for liquidity effects. Other papers related to the study in this chapter are discussed in the thesis introduction.

First, abnormal returns over 181 days straddling the transition to Phase II are examined using the market model established by Brown and Warner (1985). This means the analysis is concentrated on 90 days on either side of the first day of trading in Phase II. Secondly, volume changes following the trading of the December 2008 futures contract in Phase II are investigated, and thirdly, ratios of bid-ask spread liquidity proxies are applied after the method of Hedge and McDermott (2003) to determine liquidity changes. The basic motivation for applying the bid-ask spread ratios methodology is that bid-ask spreads are adequate measures of event impacts on liquidity of financial instruments. Dennis and Strickland (2003), Pham et al. (2003), Cao et al. (2004), Schrand and Verrecchia (2005) and Lesmond et al. (2008), all employ similar approaches. Liquidity measures play an important role in finance and hence have attracted tests of robustness. Goyenko et al. (2009) in an important paper examine the most commonly used measures of liquidity in finance literature. When measured against specific benchmarks, liquidity measures based on trading spread usually win the horserace on robustness. This chapter implements ratios of the quoted



and relative bid ask spread measures. However, Lee and Ready (1991) indicate that the relative bid-ask spread may be an inaccurate measure of liquidity if many trades occur with the bid and ask prices. As this study uses only daily transactions data from the EEX, one cannot ascertain the volume of trades within the spreads; hence, for robustness the effective bid-ask spread measure after the method of Heflin and Shaw (2000) and Hedge and McDermott (2003) is also implemented.

The results obtained show significant liquidity improvements since the transition to Phase II under the new regime of rules. The improvements are not limited to the start of Phase II alone, they are maintained over 90 trading days after the transition. The study also finds significant improvements in trading volumes over the same period. The findings, when viewed in tandem with the European Commission's reports on net short emissions reports for compliance year 2008, indicate that the new regime of rules and tighter caps introduced for the Phase II trading period are correlated with improvement of market quality on the hitherto highly illiquid EEX. Also, in order to eliminate the possibility that the analysis capture calendar effects, the study investigates also liquidity effects for the start of trading in 2007 and 2009 with no significant changes recorded for the short term. Introduction of a new platform security-related policy mid-phase seems to have the opposite effect. Results obtained suggest that EC Regulation (EC) No 994/2008 of 8 October 2008 is linked to significant loss of liquidity in the December-2009 EUA futures contract, since there is evidence of declining short term liquidity around the event date. For the release of compliance results for years 2007 and 2008, results suggest that the announcements are associated with short and long term liquidity improvements. None of the events tested show significant positive abnormal returns for any of the EUA futures contracts.

The remainder of this chapter is arranged as follows: Section 4.2 discusses the trading environment on the EEX. Section 4.3 reports on the data, section 4.4 discusses the methods and results of the analysis. And section 4.5 concludes the chapter.

## **4.2. The Trading Environment on the EEX**

The EEX currently offers trading in emission allowances spot and derivatives. The underlying for each futures contract on the EEX is 1,000 EUA (1,000tCO<sub>2</sub>) and the settlement form is delivery versus payment. There are currently two delivery dates in December: Early and mid-December, trading has exclusively been on the mid-December contracts. Electronic trading continuously takes place between 0900hrs and 1700hrs CET on trading days. Prices are quoted in Euros with a minimum tick of €0.01 per tCO<sub>2</sub> by the sole market maker RWE Supply and Trading GmbH. Electronic trading perhaps is the best option for the EEX in view of the low daily trading averages. In more conventional markets, the introduction of electronic trading with market makers has been found to have greatly improved liquidity (see Barclay et al., 1999; Domowitz, 2002).

All transactional settlements and allowances booking within the bounds of the national register (German Emissions Trading Authority) on the exchange are guaranteed by a clearinghouse, the European Commodity Clearing AG (ECC). The EEX offers trading in EUA spot (2008-2012), EUA futures, EUA options and CER futures. The platform also offers daily auctions alongside continuous trading; the brokered prices on these auctions are published daily as the EEX Carbon Index (Carbix®). The auctions are at the behest of the German Federal Ministry of Environment and they represent 10% compulsory auctionable NAP allocations for German installations. Trading volume on the EEX has since 2010 advanced rather rapidly. This is due to the decision of Europe's largest CO<sub>2</sub> emitter, RWE AG to shift some of its carbon trade from the ECX to the EEX (Carr, 2010).

## **4.3. Data**

### **4.3.1. Sample Selection**

First, calendar time is converted to event time (see Beneish and Gardner, 1995; Gregoriou and Ioannidis, 2006). 2<sup>nd</sup> January 2008, which is officially the first day of trading in Phase II, is defined as event day 0 for the investigation of liquidity effects after the onset of trading in Phase II. The Dec-2008 EUA futures contract that has been trading on the EEX since during the first phase is then selected for this analysis

because it satisfies the following conditions and also account for more than 85% of trading volume during the period: 1) The contract has historical data for a period of 90 trading days before and after the event; 2) The contract is the most actively traded contract on the exchange 90 trading days before and after the event. A scarcity of transactions on the EEX is observed such that at any one period only one or two contracts are sufficiently traded, hence events are examined using the most actively traded contract at the period during which the event occurred.

The study is extended to include three other events (see Table 4.1).<sup>16</sup> Conditions (1) and (2) above are applied in the selection of EUA futures contract to be examined for liquidity effects of the other events. The events chosen must satisfy the following condition only: 1) No other event/announcement of relevance to the market occurs within 90 days before and after the chosen event in order to avoid the problem of confounding effects.

Daily data on trading volume for all futures contracts traded on the EEX over the time period of 4th October 2005 to 30<sup>th</sup> December 2010 is obtained from EEX. The data period extends beyond this chapter's immediate enquiry for the purpose of providing a descriptive view of market variables over an extended period (see Table 4.2). Daily best bid and ask prices are obtained along with daily trading variables (including volume and open interest) and the last transaction price and time for each day. The only intraday variable is the last transaction price for each day; this is required in estimating the effective bid-ask spread.

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<sup>16</sup> Initially, 42 events over a 41-month period stretching from August 2007 to December 2010 were preliminarily explored for liquidity shocks potential. From these 12 were selected for full methodological assessment, however only four events with sufficient statistical impacts for volume and liquidity effects are reported. All the remaining eight events show from virtually no significant results.

**Table 4.1. Table of Events and Corresponding Dates**

This table lists the events that are examined for their liquidity impacts on EEX EUA futures contracts. The contracts used for each event are listed in the fourth column of the table.

<b>Date</b>	<b>Event tag</b>	<b>Event Description</b>	<b>Contract used in testing impact of event</b>
02/01/2008	Event 1	First day of trading EUA futures contracts in Phase II	EEX EUA Futures December 2008
08/05/2008	Event 2	Release of verified emissions retirement data for compliance year 2007	EEX EUA Futures December 2008
08/10/2008	Event 3	"Commission Regulation (EC) No 994/2008 of 8 October 2008 (Amendment to the Commission regulation (EC) No 2216/2004 of 21 December, 2004) for a standardised and secured system of registries pursuant to Directive 2003/87/EC of the European Parliament and of the Council and Decision No 280/2004/EC of the European Parliament and of the Council"	EEX EUA Futures December 2009
11/05/2009	Event 4	Release of verified emissions retirement data for compliance year 2008	EEX EUA Futures December 2009

### 4.3.2. Sample Description

In Panels A and B of Table 4.2, summary statistics for the market liquidity proxies and trading activity measure of daily traded volumes are presented. Panel A is for Phase I and Panel B, Phase II. The evidence points to higher intertemporal fluctuations in daily volume than the liquidity proxies; this is implied by the higher coefficients of variation. This may be due to the fact that bid and ask prices are essentially discrete variables; this property helps in diminishing the potential for volatility through price clustering (Chordia et al., 2001). Further, in Panel A, there is substantial level of variation between the relative and effective bid-ask spread values. This implies that a vast proportion of carbon trading occurs within the ask and bid quotes provided by the market maker.

It is also of interest to note that the high levels of bid-ask spreads, and the low average trading volume of the carbon permits in Panel A suggest that the emission permits are illiquid in Phase I of the EU-ETS. This is not surprising in view of the lack of trading volumes linked with the over allocation of carbon permits. To provide an expansive view of liquidity changes in the EU-ETS, quarterly measures of six liquidity proxies are provided in Panel C of Table 4.2 as part of the descriptive analyses. The Panel shows that liquidity has considerably advanced over Phase II.

**Table 4.2. Descriptive Statistics**

Panels A and B provide descriptive statistics for daily bid-ask spread values for EEX EUA futures contracts trading on the EEX platform between 4<sup>th</sup> October 2005 and 30<sup>th</sup> December 2010. A and B are for Phase I and Phase II respectively. Panel C shows daily liquidity measures per quarter using data over the same period. The quoted bid-ask spread is the difference between the daily best ask and bid prices, the relative bid-ask spread is the daily ask price minus the best bid price divided by the daily best mid-quote, effective bid-ask spread is twice the absolute value of the prevailing transaction price minus the daily best mid-quote. Coefficient of variation is the ratio of standard deviation to median. Depth (€Depth) is computed as the difference between open interest (euro value of open interest scaled by 1000) at  $t$  minus  $t_{-1}$ . CompositeLiq is the value of %relative spread divided by €Depth. All values are computed by obtaining the averages for each individual contract trading during the period and then cross-sectionally aggregating across the range of contracts. Each EUA futures contract has an underlying of 1000 tonnes of CO<sub>2</sub>. Excluding discarded dates, the panels contain data for 1,280 trading days.

**Panel A: Phase I**

	<b>Quoted Spread</b>	<b>Relative Spread</b>	<b>Effective spread</b>	<b>Daily volume (contracts)</b>
<b>Mean</b>	46.31%	3.62%	32.87%	46.26
<b>Standard Deviation</b>	0.222	0.031	0.285	81.803
<b>Coefficient of variation*</b>	0.518	1.171	1.139	8.180
<b>Median</b>	43.00%	2.62%	25.00%	10.00

**Panel B: Phase II**

	<b>Quoted Spread</b>	<b>Relative Spread</b>	<b>Effective spread</b>	<b>Daily volume (contracts)</b>
<b>Mean</b>	13.48%	0.77%	19.74%	269.560
<b>Standard Deviation</b>	0.075	0.003	0.195	359.773
<b>Coefficient of variation*</b>	0.627	0.448	1.496	2.636
<b>Median</b>	12.00%	0.74%	13.00%	136.50

**Panel C: Liquidity Proxies**

Quarter	Quoted Spread (%)	Relative spread (%)	Effective spread (%)	Depth	€Depth	CompositeLiq (%)
	Mean (Median)	Mean (Median)	Mean (Median)			
<b>4<sup>th</sup> 2005</b>	64.00 (60.00)	2.92 (2.63)	42.60 (40.00)	6.45	142.94	2.04
<b>1<sup>st</sup> 2006</b>	59.00 (60.00)	2.20 (2.11)	29.83 (25.00)	14.08	369.29	0.60
<b>2<sup>nd</sup> 2006</b>	68.00 (62.00)	3.45 (3.37)	62.19 (45.00)	9.92	205.71	1.68
<b>3<sup>rd</sup> 2006</b>	44.00 (45.00)	2.55 (2.59)	22.37 (15.00)	7.18	125.03	2.04
<b>4<sup>th</sup> 2006</b>	51.00 (43.00)	3.58 (3.04)	27.10 (10.00)	12.52	179.36	1.99
<b>1<sup>st</sup> 2007</b>	36.00 (37.00)	2.14 (2.62)	20.83 (15.00)	10.03	113.90	1.88
<b>2<sup>nd</sup> 2007</b>	35.50 (33.00)	2.75 (1.95)	28.15 (15.00)	47.83	997.13	0.28
<b>3<sup>rd</sup> 2007</b>	36.00 (36.70)	8.10 (7.70)	34.35 (30.00)	81.91	1671.68	0.48
<b>4<sup>th</sup> 2007</b>	23.00 (21.00)	3.30 (1.30)	27.66 (30.00)	49.77	1117.78	0.30
<b>1<sup>st</sup> 2008</b>	17.00 (12.70)	0.76 (0.57)	15.77 (12.00)	111.76	2423.24	0.03
<b>2<sup>nd</sup> 2008</b>	17.00 (16.80)	0.62 (0.63)	16.50 (11.00)	86.55	2260.25	0.03
<b>3<sup>rd</sup> 2008</b>	21.00 (21.30)	0.81 (0.84)	23.00 (17.50)	179.03	4397.99	0.02
<b>4<sup>th</sup> 2008</b>	23.00 (22.00)	0.99 (1.02)	24.12 (19.00)	404.80	7795.26	0.01
<b>1<sup>st</sup> 2009</b>	14.00 (11.50)	1.10 (0.99)	23.42 (15.00)	72.33	837.59	0.13
<b>2<sup>nd</sup> 2009</b>	14.60 (14.30)	0.98 (0.94)	28.67 (16.00)	67.15	939.52	0.10

<b>3<sup>rd</sup> 2009</b>	13.00 (14.00)	0.88 (0.88)	16.38 (8.50)	43.20	622.33	0.14
<b>4<sup>th</sup> 2009</b>	12.80 (12.30)	0.88 (0.86)	20.64 (13.00)	57.30	797.81	0.11
<b>1<sup>st</sup> 2010</b>	10.50 (10.30)	0.77 (0.76)	21.57 (15.00)	133.83	1761.77	0.04
<b>2<sup>nd</sup> 2010</b>	10.20 (10.50)	0.65 (0.66)	24.35 (17.70)	194.13	2971.22	0.02
<b>3<sup>rd</sup> 2010</b>	7.10 (6.30)	0.47 (0.41)	14.58 (10.50)	407.62	6082.40	0.01
<b>4<sup>th</sup> 2010</b>	6.50 (5.30)	0.43 (0.35)	11.03 (8.00)	295.21	4466.57	0.01



## 4.4. Results and Discussion

### 4.4.1. Abnormal Return of Events: Dec-2008 and Dec-2009 contracts

The event study methodology and with the market model as outlined in Campbell et al. (1997) is employed in estimating abnormal returns for the EUA futures contracts Dec-2008 and Dec-2009 traded on the EEX. The market model has been used by several studies (see for example Brown and Warner, 1985; Hedge and McDermott, 2003; Denis et al., 2003; Gregoriou and Ioannidis, 2006) .

The market model assumes a linear correlation between the return of a given security with a value-weighted index. The model is given for any asset  $i$  as:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \quad (4.1)$$

$$E[\varepsilon_{it}] = 0 \quad Var[\varepsilon_{it}] = \sigma_{\varepsilon_i}^2$$

where  $R_{it}$  and  $R_{mt}$  are the time  $t$  returns on asset  $i$  and the market portfolio respectively.  $\varepsilon_{it}$  is a zero mean disturbance term, while  $\alpha_i$ ,  $\beta_i$  and  $\sigma_{\varepsilon_i}^2$  are parameters of the model. Abnormal return will be obtained from the market model as follows:

$$\varepsilon_{it}^* = R_{it} - E[R_{it}|X_t] \quad (4.2)$$

$R_{it}$ ,  $E[R_{it}]$ , and  $\varepsilon_{it}^*$  correspond to the actual, normal and abnormal returns respectively.  $X_t$  is conditioning information corresponding to the market return (Campbell et al., 1997). The LEBA carbon index is used in estimating the model parameters over 90 days prior to the events. The Index is computed for every trading day in the sample employing value-weighted average of all carbon trades executed by LEBA firms. Abnormal return for each trading day in the event windows are obtained after OLS estimation with Newey and West (1987) HAC. These are then aggregated through time to obtain cumulative abnormal return (CAR) for each window investigated.

The average abnormal returns (AAR) for each event window are reported in Table 4.3. The results in the second column of the table suggest that the onset of trading in Phase II is not associated with significant abnormal returns for the Dec-2008 although the abnormal returns are positive on the short term. On the long term, the abnormal returns are negative and also not significant. Table 4.3 also reports results for Events 2, 3 and 4. The results indicate that none of the events are related to significant abnormal returns for the tested December maturity contracts; however, again, a number of the abnormal return estimates are positive. The predominantly positive values although not significant may be construed as a suggestion of price appreciation due to the events (especially with Event 1). The negative long-term AAR values however indicate that if this were accurate, the price improvements in any case are not permanent. According to Campbell et al. (1997), the large  $R^2$  values obtained in the market model estimation indicate corresponding variance reduction thereby leading to gain in model specified. The  $R^2$  values are 0.81, 0.58, 0.62 and 0.72 for Events 1, 2, 3 and 4 respectively.

**Table 4.3. Average Abnormal Returns**

Average Abnormal Returns (AAR) using the market model (estimated using OLS with Newey and West, 1987 HAC) are computed for an event study aimed at determining excess returns around the events' days. The estimation window for estimating the model parameters is 90 days before and after the events (-90, +90). AAR is then tested for being significantly different from zero by with a regular t-statistic. t-statistics are reported underneath the AAR values in each corresponding event window and event boxes. Event 1 is the transition of trading from Phase I to Phase II. Event 2 and Event 4 are dates for the release of emissions verification results for compliance years 2007 and 2008 respectively. Event 3 is the date for the adoption of EU Commission regulation (EC) No 994/2008 of 8<sup>th</sup> October 2008. Event 1 and Event 2 are investigated using the December 2008 contract, and Event 3 and Event 4, the December 2009 contract. BG-LM and BPG are the p-values for the Breusch-Godfrey serial correlation and the Breusch-Pagan-Godfrey (heteroscedasticity) LM test statistics respectively. One EUA Futures contract has an underlying of 1000 EUAs. \*\*\* indicates statistical significance at 1% level, \*\* indicates statistical significance at 5% level and \* indicates statistical significance at 10% level.

Event window	Event 1	Event2	Event 3	Event 4
	AAR (%)	AAR (%)	AAR (%)	AAR (%)
[-1, +1]	0.48	-0.20	-0.23	-0.21
	1.02	-0.40	-0.29	-0.12
[-2, +2]	0.36	-0.16	0.49	0.40
	1.23	-0.44	0.78	0.36
[-3, +3]	0.29	-0.25	0.17	0.40
	1.27	-0.89	0.36	0.51
[-4, +4]	0.08	-0.08	0.02	-0.09
	0.36	-0.28	0.06	-0.12
[-5, +5]	0.00	0.10	0.06	-0.03
	0.001	0.39	0.18	-0.04
[0, +10]	-0.25	0.10	0.02	0.36
	-0.98	0.43	0.03	0.45
[0, +20]	-0.31	0.14	-0.12	0.03
	-0.71	0.78	-0.28	0.06
[0, +30]	-0.10	0.06	-0.21	0.05
	-0.3	0.43	-0.66	0.15
[0, +60]	-0.04	-0.07	-0.06	0.03
	-0.19	-0.40	-0.26	0.13
[0, +90]	-0.02	-0.03	-0.07	0.03
	-0.12	-0.21	-0.34	0.22
Adjusted R <sup>2</sup>	0.81	0.58	0.62	0.72

BG-LM	0.00	0.08	0.06	0.11
BPG	0.19	0.12	0.17	0.54

#### 4.4.2. Impact of Events on Trading Volumes: Dec-2008 and Dec-2009 contracts

##### *Short Term Impact of Events*

The presence of abnormal trading volume in the event period is investigated by employing the following dummy time series regression model:

$$Volume_t = \alpha + \sum_{-5}^{+5} D_i \beta_i + \varepsilon_i \quad \text{for } t = -90, +5 \quad (4.3)$$

Where  $Volume_t$  is the logarithmic transformation of trading volume for the futures contract at day  $t$ .  $\alpha$  is a constant,  $D_i$  are dummy variables for each trading day in the event window  $[-5, +5]$ . The coefficients of the eleven dummy variables,  $\beta_i$  capture the abnormal trading volume over the event window,  $[-5, +5]$ ,  $\varepsilon_i$  is a random disturbance term with a mean of zero and a variance  $\sigma^2$ .  $\alpha$ , and  $\beta_i$  are parameters to be estimated. Equation (4.3) is estimated by OLS with White's (1980) heteroscedastic consistent covariance matrix and Newey and West (1987) HAC, the statistical inference levels obtained are significantly the same.

The results for the time series regression are reported in Table 4.4. The positive and significant sign of the eleven dummy variables suggests an improvement in trading volumes of carbon permits being associated with the start of trading in Phase II. Following the introduction of Phase II, the abnormal volume continues to be positive and significant throughout the post announcement period. The association is underscored by the fact that January 2<sup>nd</sup> and 3<sup>rd</sup> 2008 (the first and second days of trading in phase II) have two of the three largest estimates in the 11-day period examined with 2.27 and 2.28 respectively. They have respective t-statistics of 10.82

and 10.87, values significant at 1% levels. After the 3<sup>rd</sup> of January 2008, the abnormal volume decreases from the peak values but remains positive and significant at 5% level.

The results for Events 2, 3 and 4 are presented in the last three columns of Table 4.4. For Events 2 and 4, there are significant positive estimates reported once the emissions verification results were released. This indicates relative upsurge in trading volumes. For Event 3, three of the post-event estimates are negative with two positive. All estimates are statistically significant, thus the result is not conclusive with respect to association of the event with trading volumes. The liquidity effects are thus examined in the next section. The regression for equation (4.3) also passes the normality test for all four events, implying that the abnormal volume empirical estimates are not as a result of presence of outliers in the data. Also the Augmented Dickey-Fuller test (see Dickey and Fuller, 1979) show that the null of presence of unit root is strongly rejected for the log (volume) variable in each case, hence the results are not spurious. The reported p-values are MacKinnon (1996) one-sided p-values

**Table 4.4. Short Term Trading Volume changes around Events**

The following time series regression model is estimated (using both White' (1980) heteroscedastic consistent covariance matrix and Newey and West (1987) HAC alternatively) to examine trading volume changes around the events' days on specific EEX EUA futures contracts:

$$Volume_t = \alpha + \sum_{-5}^{+5} D_i \beta_i + \varepsilon_t, \quad \text{for } t = -90, +5$$

where  $Volume_t$  corresponds to the log of the traded volume for day  $t$ .  $\alpha$  captures the trading volume variations over the 96 day estimation period and  $D_i$  are dummy variables representing each day in the investigated event window (-5, +5). The coefficients of all eleven dummy variables encapsulate the variations in trading volume over the event window, one for each day in the event window (-5, +5).  $\varepsilon_t$  is a residual term with  $E[\varepsilon_t] = 0$  and  $Var[\varepsilon_t] = \sigma^2$ .  $\alpha$  and  $\beta_i$  are parameters for estimation. The estimates are reported in the boxes with corresponding t-statistics underneath. Event 1 is the transition of trading from Phase I to Phase II. Event 2 and Event 4 are dates for the release of emissions verification results for compliance years 2007 and 2008 respectively. Event 3 is the date for the adoption of EU Commission regulation (EC) No 994/2008 of 8<sup>th</sup> October 2008. Event 1 and Event 2 were investigated using the December 2008 contract, and Event 3 and Event 4, the December 2009 contract. NORM (1) and ADF are the p-values for the Jarque-Bera normality test and the Augmented Dickey-Fuller test statistics respectively. The lag length for ADF is selected on the basis of Schwarz information criterion (Schwarz, 1978). \*, \*\*, \*\*\* correspond to statistical significance at 10, 5 and 1% levels respectively.

Parameter	Event 1	Event 2	Event 3	Event 4
	Estimates	Estimates	Estimates	Estimates
$\alpha$	3.00	4.90	2.71	3.99
	14.33***	51.64***	11.88**	23.57***
$\beta_{-5}$	1.55	0.28	-2.71	-1.59
	7.39***	2.96***	-11.88**	-9.39***
$\beta_{-4}$	1.70	-0.36	1.20	-3.99
	8.09***	-3.77***	5.27**	-23.57***
$\beta_{-3}$	1.09	0.52	1.30	0.57
	5.20**	5.42***	5.69**	3.35**
$\beta_{-2}$	3.00	0.04	2.64	0.19
	14.33**	0.43	11.57**	1.11
$\beta_{-1}$	0.91	-0.74	4.31	0.83
	4.33***	-7.82***	18.91**	4.93***
$\beta_0$	2.27	0.18	3.76	0.52
	10.82***	1.93*	16.49**	3.10***
$\beta_{+1}$	2.28	0.46	-2.71	1.68
	10.87***	4.85***	-11.87**	9.96***
$\beta_{+2}$	1.90	0.46	-2.71	0.51

	9.06***	4.85***	-11.88**	3.03***
$\beta_{+3}$	1.42	0.71	-0.41	0.19
	6.75***	7.50***	-1.78*	1.11
$\beta_{+4}$	1.38	0.19	1.51	0.99
	6.57***	2.02**	6.62**	5.86***
$\beta_{+5}$	1.94	0.56	2.98	1.08
	9.24***	5.87***	13.06**	6.36***
$R^2$	0.12	0.04	0.18	0.12
NORM (1)	0.17	0.10	0.17	0.11
ADF	0.00	0.00	0.00	0.00

#### *Long Term Impact of Events*

In order to analyze changes in the long term trading volume of carbon permits preceding Phase II EU-ETS trading and other events, Post/Pre ratio of long term trading volume in the post event period [0, +90] to the long-term volume in the pre event period [0, -90] is constructed. If there is sustained increase in trading volume (over 90 trading days) when the Dec-2008 contracts are traded in Phase II as against when traded in Phase I, this may lead to increasing economies of scale for the market maker, resulting in lower bid-ask spreads and higher market liquidity (Copeland and Galai, 1983).

The results from analysis of long-term changes in trading volume are reported in Table 4.5. The mean (median) Post/Pre ratio of trading volume is 5.28 (5.21) for Event 1, this is with a corresponding t-statistic of 13.05. This is another evidence of the association of commencement of trading in Phase II with improvements in trading volumes. For Events 2 and 4, which are the announcement dates for verified emissions results, statistically significant Post/Pre ratios are also observed, further underscoring the positive association of the release of the events with trading volume improvements. The respective mean (median) values for Post/Pre ratio for Events 2 and 4 are 1.50 (1.34) and 2.66 (2.59).

**Table 4.5. Long Term Trading Volume Around Events**

The sample consists of futures contracts on carbon permits that were traded before and after the introduction of Phase II of the EU-ETS. Changes in long term trading volume are defined as trading volume in futures contracts in the post event period [0, +90] divided by the trading volume in futures contracts in the pre event period [0, -90]. The t-statistic is constructed to test the null hypothesis that the trading volume is unchanged in the pre event period as compared with the post event period.

Variable	Long-term Trading Volume			
	Event 1	Event 2	Event 3	Event 4
Mean (Post/Pre)	5.28	1.50	4.72	2.66
Median (Post/Pre)	5.21	1.34	4.62	2.59
t-statistic	13.05***	2.20**	3.76***	2.62**

Also, an interesting result is the recording of large and statistically significant Post/Pre ratios for Event 3. This chapter further examines this in section 4.4.3 to see whether the observed long-term improvement is accompanied by long-term improvements in liquidity. The estimates in Tables 4.4 and 4.5 provide very little indication of what to expect since liquidity and trading volumes are weakly related, in fact the innovations of both variables can be conditionally uncorrelated (Johnson, 2008). In section 4.4.5, the liquidity effects are examined; however, some discussions on measuring financial markets liquidity are first presented in sections 4.4.3 and 4.4.4.

#### 4.4.3. Financial Markets Liquidity

In the introduction to this thesis, the common basis liquidity shares with other microstructure properties of financial markets is discussed, here the focus is on quantifying liquidity. According to Sarr and Lybek (2002), liquid securities/markets usually manifest some or all of the following five features: tightness, immediacy, depth, breadth, and resiliency. Tightness refers to low costs of transaction as is evident in quote driven markets with bid and ask prices; the narrower the spreads between the ask and bid, the lower the transaction costs and the higher the liquidity. Immediacy is a measure of speed of transaction. Depth and breadth are both reflected by the availability of orders and large volumes of securities (willing traders) ready for transactions as required. There will always be a degree of disproportional trading with respect to generating buy and sell orders especially on short run basis (Chordia and Subrahmanyam, 2004); resiliency refers to the market's ability to generate new



orders to correct such short run inconsistencies. These five features correspond to Kyle's (1985) three features of liquidity, which include tightness, depth, and resilience.

The above definition captures the qualitative concept of liquidity but the quantitative assessment is still a source of controversy in academic literature (see for example Baker, 1996; Sarr and Lybek, 2002; Hallin et al., 2011). And as the role of liquidity in empirical finance has matured to the extent of critically affecting decisions on asset pricing, general market efficiency and corporate finance, so has the interest generated by this concept among practitioners and academics alike grown (see Goyenko et al., 2009). Measuring financial markets liquidity is contingent on the possibility of substitutability of asset classes traded on that market and the extent of liquidity of the assets. The availability of a range of issuers for individual assets can create a difficulty leading to fragmentation in the market, thereby engendering loss of fluidity. This is not the only obstacle to measuring market liquidity based on the liquidity measures of component assets; similar asset classes having the same issuer may also have observable peculiarities under differing conditions. Examples of these potential differences include varying maturities in the case of futures and options. These represents a fundamental problem involved in blending individual measures of liquidity of different assets together to arrive at an acceptable and unbiased measure of market wide liquidity. This has led to relatively limited number of studies being carried out on market wide liquidity over the years (see Chordia et al., 2001). However, some of the problems are solvable, for example, if market liquidity is treated as a dynamic factor, time dependence and commonness can be controlled for simultaneously (see Hallin et al., 2011).

#### **4.4.4. Measures of Liquidity**

Three key groupings of liquidity measures in finance literature (see for discussions Grossman and Miller, 1988; Hasbrouck and Schwartz, 1988; Chordia et al., 2001; Sarr and Lybek, 2002; Hallin et al., 2011) are discussed in this section.

*Volume Based Measures*

Although higher volume of transactions is not necessarily correlated with improvements in market liquidity (see Johnson, 2008). Volume based measures are commonly used in determining the liquid state of a market; for example in Panel C of Table 4.1, two depth measures are used as liquidity proxies, also turnover is employed as proxy for liquidity the regression analysis in chapter 3 of this thesis. This is tenable since market transactions executed in significant numbers provide vital order flow information to market participants. For market makers in a quote driven market, this allows for the evaluation of the correctness of their quotes, changes in quotes ultimately lead to righting of order flow to reflect efficient price signal. This implies that the market is resilient. This is a continuous activity, consistently supplying needed information to the participants on the nature of price transformations.

Markets lacking in both depth and breadth do not provide this vital stream of information to market participants and this has huge implications for market efficiency. Frequent trade interruptions and general lack of price continuity evident on most emissions trading platforms in Phase I of the EU-ETS and to some extent in Phase II is informed by the absence of depth and breadth. Issues such as this breed unpredictability in markets, especially when it comes to price signalling. Uncertainty about price signals can however be overcome by looking to similar markets/platforms with more depth and wider breadth as is the case in the EU-ETS, and this is where substitutability of assets plays a key role. The European Climate Exchange ICE platform is responsible for about 90% of exchange based transactions in the EU-ETS (see Daskalakis et al., 2011) and thus leads the price discovery process (see Mizrach and Otsubo, 2011; Benz and Klar, 2008). Thin trading volumes on less liquid EU-ETS platforms therefore need not inhibit trading as order flow balances can be spurred from the more liquid platforms.

Moreover, trading enhancement need not be down to liquidity exclusively, if possible buyers and sellers are easily discernible, this also can spur trading. This seems to be the case for the EU-ETS. The market is mandatory for some 12,000 participants and there are others who trade for other purposes such as risk hedging and for liquidity. These participants who must trade for compliance purposes in the market are readily

identifiable; hence the thriving of OTC trades at the start of the EU-ETS. In literature the use of volume figures has mostly been tailored towards evaluating the level of market participation and the volume of instruments. Volume analysis is usually carried out in connection to outstanding volumes of the relevant security. It requires more than relating traded and outstanding volumes. Study of significant shifts in market volumes in reaction to announcements and events are also critical to market liquidity conclusions.

#### *Price Movement and Market Resilience Measures*

Price movements in a market can result from liquidity fluctuations in the market; the fluctuations can also be exogenous. This category of measures aims to distinguish liquidity influenced price movements and those that occur as a result of other unaccounted factors. These measures relate to price discovery (efficiency) and resilience. Most price-based proxies of liquidity harness a fundamental view of price movements in liquid and illiquid markets. There is a continuous element to price changes in liquid markets that is absent in illiquid ones. Although there will be some form of transient change to prices even in a liquid market due to exogenous shocks. Shocks-induced jumps affects price discovery but the continuity in price formation should still be sustained (see Sarr and Lybek, 2002). Hence when a lasting price shift occurs, the effect should be such that the temporary elements of the price change will be very little in comparison to an illiquid market's. The Market-Efficiency Coefficient (MEC) of Hasbrouck and Schwartz (1988) which exploits this element of price change is one of such measures. It describes a coefficient differentiating transitory and permanent price shifts. The coefficient formation is a process expressed as:

$$MEC = \text{Var}(R_t) / [T \times \text{Var}(r_t)] \quad (4.4)$$

where  $\text{Var}(R_t)$  is the variance of the log of long period returns,  $\text{Var}(r_t)$  is the variance of short period returns and T corresponds to the number of short periods in each longer period. The ratio in markets exhibiting higher levels of resilience (liquidity) should be slightly lower than one. In those with low levels of resilience, the ratio will be considerably lower than one. The difference in ratios is accounted for by the variance in short-period price volatility in the different markets. Bernstein (1987)

identifies several factors influencing disproportionate short-period price volatility, these include intervention in the price formation process by the market maker, errors in price discovery, and this may also be linked to meddling by market makers. Erroneous price formation includes lagged price reaction to pertinent announcements/events bringing about positively correlated price shifts incrementally. This diminishes short-period volatility in correspondence to long-period volatility ultimately leading to MEC rising above one.

The MEC is basically a variance ratio test of the random walk. The variance of long-horizon returns are divided by the variance estimated for returns over shorter intervals. For a market in harmony with the random walk process, the variance of returns measured over longer horizons is equal to the sum of variances of shorter horizon returns as long as the summation of the shorter horizons are equal to that of the longer horizon. Thus, variance of the longer horizon returns is  $\eta$  times the variance of returns measured over shorter horizons, if  $\eta$  is the number of short horizon periods in the longer horizon. According to Grossman and Miller (1988), divergence from random walk can be induced by inventory related issues due to return serial correlation, however in a largely efficient market; arbitrage opportunities created by this deviation will lure participants into providing required trading volumes. Hence the divergence from random walk will be very much temporary even if market makers cannot absorb orders.

In building a case for use of price based measures as proxies for liquidity, this thesis has sought to tie in price continuity with market resilience. Market resilience and price continuity are not exact alternates. Participants in the market trade either for liquidity purposes or to take advantage of private information and the positions they take are reflected in the orderflow. Irrespective of these positions, they all respond to shifts in fundamentals although markets do become skewed without being prompted by changes to fundamentals as noted by Grossman and Miller (1988). If we imagine that this is the case thereby resulting in a swing of market participants to one end of the market spectrum, a price shift will occur. Expectedly, a resilient market will promptly generate orders (mainly arbitrage market orders) to correct the imbalance of both the participants' shift to one end of the market and the corresponding price shift. The price is therefore prevented from further progressing on its current course by the

influx of new orders aimed at correcting the imbalance (see Chordia et al., 2008; Chordia et al., 2002). The situation perhaps then resolutely leads to increased price continuity, hence the connection between market resilience and price continuity.

### *Transaction Cost Measures*

Analysis of transactions prices provides a means of distinguishing several cost factors such as costs associated with order processing, information asymmetry and inventory. In quote driven markets, the market maker quotes provide a basis for measuring transactional spreads (bid-ask spreads). These spreads contain cost components that can be deciphered by scrutinizing their time series. Such cost components will include asymmetric information/adverse selection costs, inventory costs and order processing costs. Campbell et al. (1997) identify order processing, inventory and adverse selection costs as the three basic economic information sources in market microstructure models.

Order processing costs are associated with the direct price of executing transactions in a given market. Inventory costs are those that come with having to hold the financial securities, usually costs associated with record keeping. In the EU-ETS, the basic inventory cost incurred will be the cost of operating and setting up recording device to keep track of transactions. Situations arise in a market, such that an investor is more informed than the market maker. When this occurs, the market maker is at a disadvantage and may end up incurring losses based on this anomaly. The cost associated with this is known as adverse selection costs. Market makers are required to provide liquidity in a quote driven market and hence must trade with all participants when the need arises with no ability to discern if a participant is better informed than them or otherwise. It is only appropriate then that a portion of the spread offered by a market maker be for adverse selection costs, a compensation for the potential losses that may be incurred as a result of trading with an informed trader.

Based on the varying properties of these costs, they possess distinctive statistical characteristics; this spurred the growth of asymmetric information and inventory costs literature in the 1970s and 1980s. This development provided unambiguous projections on computing the bid-ask spread (see as examples Ho and Stoll, 1981; Ho and Stoll, 1983; Roll, 1984; Glosten and Milgrom, 1985; Glosten, 1987).

Advancements were also recorded in deriving adequate estimators for spread components based on the existing theories (see as examples Glosten and Harris, 1988; Stoll, 1989; Hasbrouck, 1991a; Hasbrouck, 1991b; Foster and Viswanathan, 1993).

Demand for transactions is usually adversely affected by large trading costs; indeed a characteristic of most liquid markets is low transaction costs. Reasonably low transaction costs can engender diversification, a vital condition for sustenance of market liquidity in scheme like the EU-ETS. High costs of transacting in a market can however result in fractured markets since a great deal of trades will be executed inside the spreads rather than the vicinity of the equilibrium price (all available information considering). This can consequently result in a market lacking depth (low liquidity). Moreover, wide spreads which signifies high transaction costs or presence of informed trades can force participants to seek trading opportunities on parallel platforms thus leading to thin trading. Low level of participation in markets means that the market is thin, therefore lacking breadth. Resilience in the market can also be threatened since the flow of orders will be reduced thereby reducing the capacity of the market to rectify market imbalances in order flow.

The bid-ask spread is a cost measure proxy for liquidity in empirical finance. There are several variants of the bid ask spread in microstructure literature, but perhaps the most popular is the quoted bid-ask spread. This is a measure of the difference between the lowest ask price and the highest bid price during a specific period  $t$  for a security  $i$  and it represents the economic significance of transactions to the market maker. Sometimes, valid quotes can arise in form of a regular trader issuing limit orders. Various other variants are measures that include weighted transaction prices. In a market where there is more than one market maker and they are not compelled to issue the same quotes or even trade at those quotes, distinction should be made between market maker spreads and the market spread, outliers should also be overlooked in computing a single spread for the market.

Needless to state however, no singular measure can measure all the relevant dimensions: breadth, resilience, depth, immediacy and tightness. Indeed, Hallin et al. (2010:1) identify the task of achieving concurrence on liquidity measures as: *“...double difficulty (which) seriously challenges the objectivity of any final*

*assessment*". In the next section, liquidity proxies based on the bid-ask spread are computed in order to observe liquidity effects of the events on the Dec-2008 and Dec-2009 contracts.

#### **4.4.5. Liquidity improvements: Dec-2008 and Dec-2009 contracts**

Given the short and long-term changes in trading volume effects of carbon permits due to the introduction of Phase II of the EU-ETS reported in Tables 4.4 and 4.5, market liquidity effects of the events are now tested. In order to analyse the impact of the start of Phase II EU-ETS trading and other events on the short term liquidity of carbon permits, ratios of the daily average quoted, relative and effective bid-ask spreads over various event windows in the pre and post Phase II trading period are constructed. The relative bid-ask spread is computed as the ask price minus the bid price divided by the mid-price. However, as pointed out by Lee and Ready (1991) the relative bid-ask spread has two potential shortcomings. First, it overstates the trading costs of securities because it fails to account for the tendency of prices to rise following a purchase and fall following a sale. Second, it can be argued that the relative bid-ask spread is an inappropriate measure of instrument liquidity due to the fact that trades frequently occur within the ask and bid prices. Therefore, to account for these two shortcomings, the effective bid-ask spread after the methodology of Hedge and McDermott (2003) is also computed. Effective bid-ask spread is defined as twice the absolute value of the difference between trade price and the prevailing mid-price. There is also a potential problem with the use of either the relative or the effective bid-ask spread. The problem is that any event that changes the mid-price, will automatically impact upon the relative and effective bid-ask spreads. Therefore, for completeness, the quoted bid-ask spread defined as the ask price minus the bid price is also computed. The quoted spread is immune to this problem. The quoted bid-ask spread is also constructed because it is a measure that encapsulates the economic significance of trades to the market maker (Branch and Freed, 1997).

There is evidence from Table 4.6 that bid-ask spreads are significantly reduced after the introduction of Phase II EU-ETS trading. For example, in the [-5, +5] event window the mean and median quoted bid-ask spread ratios are 0.59 and highly significant. This indicates that trading spreads are significantly reduced over the 11

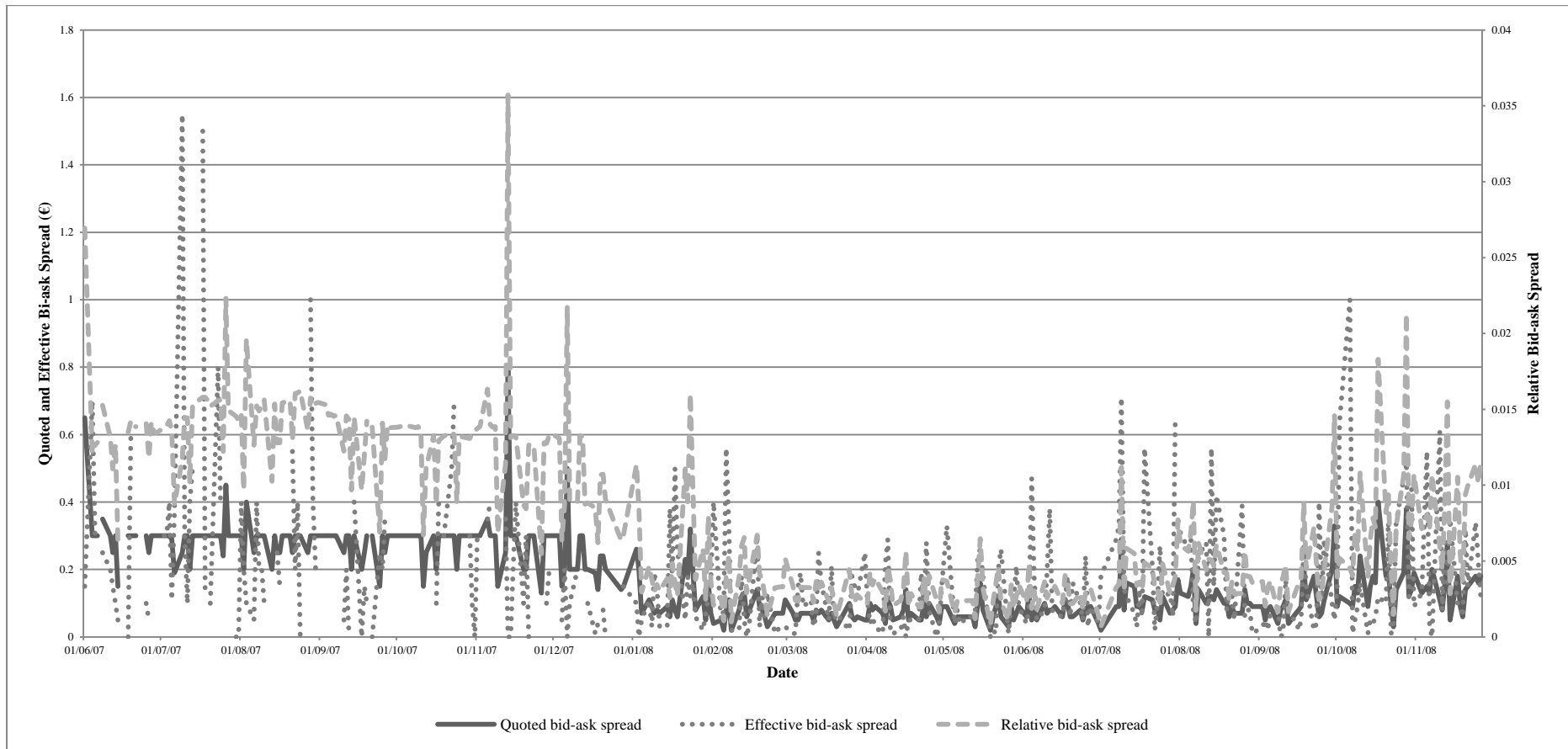
trading day period around the day of the introduction of Phase II EU-ETS trading. The significant spread reductions over the longer event time intervals such as  $[0, +60]$  and  $[0, +90]$  indicate that the reduction in trading costs is not reversed for up to 90 trading days after the start of Phase II trading. This implies that changes made to trading rules and the tightening of emission caps for Phase II are both associated with liquidity improvements. The significant decline in the bid-ask spread remains intact regardless of which liquidity measure employed as can be seen in Table 4.6.

Figure 4.1, showing the time series plot of the quoted, relative and effective bid-ask spread measures for the December 2008 EEX EUA futures contract from 1<sup>st</sup> June 2007 to 26<sup>th</sup> November 2008, backs this claim. The figure evidences a structural shift in spread estimates occurring about the start of trading in Phase II on the 2<sup>nd</sup> of January 2008. The figure also reiterates the narrowing of the spread measures over the long-term. The spread irregularity observed towards the end of the time series is normal for the EUA futures contracts when nearing maturity.



**Figure 4.1. Time Series of Quoted, Relative and Effective Bid-Ask Spread Estimates**

The chart shows the daily quoted, relative and bid-ask spread estimates in Euros for the December 2008 EEX EUA Futures contract. The data spans 1<sup>st</sup> June 2007 and 26<sup>th</sup> November 2008



The findings thus show a statistically significant increase in the liquidity of the Dec-2008 contract after the start of trading in Phase II of the EU-ETS. In addition, it is shown that the increase in liquidity is maintained over 90 trading days of Phase II trading.

This analysis is extended to the three other events with the results presented also in Table 4.6. For Events 2 and 4, the short term (significant) narrowing of quoted bid-ask spread ratios suggests that the release of the emissions verification results for 2007 and 2008 compliance years respectively on the CITL was positively received by the market. The emissions verification results for both 2007 and 2008 were net short after those of previous years 2005 and 2006 were net long. The verification results for 2005 and 2006 (not examined in this thesis) reveal the market was net long at 0.81 and 0.39 billion tonnes respectively. The actual net long positions are higher than these values from the CITL because some of the previously allocated 2.183 billion tonnes each allocated for both years were held back for auction and as new entrants' reserves. Further, aggregate emissions in the EU fell by 1.6% and 3.06% for 2007 and 2008 respectively. Long-term spreads however progressively widen to indicate that the liquidity improvements seen around the announcements dates are not aggressively sustained over the long term once the effects of the announcements start to wear off. This reaction sequence is not unusual in the study of events' impacts.

Short-term spread ratios for the new EC regulation (Event 3) however show that the admission by the EU Commission of a need to make more secure the state of its registries about 10 months into the commencement of the Kyoto-commitment phase may not have helped market confidence. The results suggest the event is associated with loss of market liquidity on the short term. The enactment of such policy at that point in the life of an infant market has two potential interpretations. It may enhance market confidence when viewed through the lens that the policy will improve platforms' security. Or, the policy may indicate that registries as they stand are not secure. Insecurity of registries indicates a dangerous development capable of jeopardising the EU climate change policy in its entirety. The latter interpretation seems to have been adopted by the market on that occasion, at least on the short term. The short-term spread estimates indicate that loss of liquidity is correlated with the timing of announcing the new regulation. This result underscores the estimates

obtained for short term volume changes (see Table 4.4). In Table 4.4, the negative and significant estimates indicate decrease in trading activity and correspondingly, a decrease in short term liquidity is now recorded around the event period. Long term quoted and effective spread estimates indicate that on the long-term, market liquidity start to improve significantly. This is further evidenced by results earlier reported in Table 4.5. The Post/Pre ratio mean (median) value of 4.72 (4.62) (and with t-statistic of 3.76) is an indication that on the long-term, the policy is positively related with improving market quality hinting that market confidence finally starts to improve.

**Table 4.6. Short and Long Term Liquidity Changes on the EEX**

Changes in EU-ETS liquidity in response to events are evaluated using the quoted, relative and effective bid-ask spread ratios of the EEX EUA futures contracts for December 2008 and December 2009 delivery. The ratios are constructed to compare liquidity of the selected futures contracts in the period before the events (-90) and various event windows around the event dates. The quoted bid-ask spread is the difference between the daily best ask and bid prices, the relative bid-ask spread is the daily ask price minus the best bid price divided by the daily best mid-quote, effective bid-ask spread is twice the absolute value of the prevailing transaction price minus the daily best mid-quote. The spread ratios are calculated as the ratio of the average spreads of selected contracts over the relevant event window to the average of the spreads for the pre-event period (0, -90). The mean ratios are reported along with the corresponding median ratios in parenthesis. The t-statistic is given below the values in each box. Event 1 is the transition of trading from Phase I to Phase II. Event 2 and Event 4 are dates for the release of emissions verification results for compliance years 2007 and 2008 respectively. Event 3 is the date for the adoption of EU Commission regulation (EC) No 994/2008 of 8<sup>th</sup> October 2008. Event 1 and Event 2 are investigated using the December 2008 contract, and Event 3 and Event 4, the December 2009 contract. A regular t-statistic is used to test the null hypothesis that the mean of the reported ratio for the contracts is equal to one. \*, \*\*, \*\*\* correspond to statistical significance at 10, 5 and 1% levels respectively.

	Event 1			Event 2			Event 3			Event 4		
Event window	Quoted spread ratios	Relative spread ratios	Effective spread ratios	Quoted spread ratios	Relative spread ratios	Effective spread ratios	Quoted spread ratios	Relative spread ratios	Effective spread ratios	Quoted spread ratios	Relative spread ratios	Effective spread ratios
[-1, +1]	0.74 (0.73) -2.25**	0.70 (0.67) -2.82**	0.43 (0.37) -9.23***	0.66 (0.66) -200.0***	0.58 (0.58) -383.17***	0.40 (0.34) -10.52***	1.22 (1.02) 0.58	1.39 (1.14) 0.89	1.22 (0.95) 0.43	0.74 (0.67) -3.52**	0.52 (0.48) -9.13**	0.29 (0.38) -7.51**
[-2, +2]	0.60 (0.55) -3.49**	0.57 (0.53) -3.99**	0.35 (0.37) -10.70***	0.66 (0.66) -201.1***	0.57 (0.58) -333.52***	0.48 (0.51) -8.12***	1.34 (1.02) 1.21	1.54 (1.14) 1.63	1.02 (0.95) 0.07	0.56 (0.67) -3.01**	0.54 (0.48) -7.70***	0.35 (0.38) -9.26***

<b>[-3,+3]</b>	0.59 (0.55) -4.71***	0.56 (0.53) -5.23***	0.35 (0.37) -14.91***	0.58 (0.66) -8.14***	0.51 (0.58) -10.75***	0.48 (0.51) -9.98***	1.23 (1.02) 1.07	1.40 (1.14) 1.58	0.96 (0.95) -0.15	0.78 (0.78) -3.76***	0.57 (0.59) -9.74***	0.41 (0.38) -6.01***
<b>[-4,+4]</b>	0.59 (0.55) -5.07***	0.56 (0.53) -5.55***	0.32 (0.30) -15.92***	0.68 (0.66) -4.01***	0.61 (0.58) -5.42***	0.58 (0.51) -4.30***	1.23 (1.02) 1.29	1.39 (1.14) 1.88*	0.87 (0.60) -0.62	0.80 (0.78) -3.27**	0.59 (0.59) -8.58***	0.55 (0.38) -3.67***
<b>[-5,+5]</b>	0.59 (0.55) -5.34***	0.56 (0.53) -5.82***	0.34 (0.30) -12.92***	0.70 (0.66) -3.84***	0.62 (0.58) -5.26***	0.65 (0.60) -3.48***	1.19 (1.02) 1.25	1.34 (1.14) 1.95*	0.83 (0.60) -0.93	0.90 (0.89) -1.10	0.67 (0.63) -4.78***	0.56 (0.38) -3.48***
<b>[0,+10]</b>	0.40 (0.33) -8.68***	0.37 (0.30) -9.62***	0.45 (0.37) -4.83***	0.78 (0.66) -2.20**	0.68 (0.58) -3.60**	0.51 (0.51) -4.03***	0.94 (0.70) -1.35	1.09 (0.78) 0.43	0.61 (0.23) -2.08*	0.83 (0.78) -3.28***	0.80 (0.59) -1.30	0.80 (0.43) -0.78
<b>[0,+30]</b>	0.40 (0.29) -12.97***	0.41 (0.30) -12.17***	0.56 (0.41) -4.58***	0.81 (0.77) -3.67**	0.68 (0.64) -7.41***	0.74 (0.60) -2.92***	0.96 (0.97) -0.57	1.28 (1.23) 2.65**	0.87 (0.88) -0.95	0.82 (0.78) -5.99***	0.70 (0.65) -5.06***	0.72 (0.38) -1.98
<b>[0,+60]</b>	0.33 (0.25) -25.58***	0.33 (0.26) -24.23***	0.47 (0.37) -9.43***	0.92 (0.88) -1.40	0.83 (0.77) -2.56**	1.06 (0.69) 0.27	0.72 (0.64) -4.84***	1.06 (0.99) 0.78	0.64 (0.30) -4.23***	0.80 (0.78) -5.56***	0.66 (0.64) -8.46***	0.75 (0.38) -2.44**
<b>[0,+90]</b>	0.30 (0.25) -36.96***	0.30 (0.26) -35.23***	0.43 (0.26) -13.25***	0.97 (0.99) -0.62	0.89 (0.82) -2.10**	0.97 (0.60) -0.21	0.66 (0.60) -6.34***	1.07 (1.03) 1.20	0.57 (0.28) -6.71***	0.75 (0.78) -9.44***	0.60 (0.56) -13.84***	0.66 (0.38) -4.39***

## 4.5. Conclusion

Since 2008, the world's largest mandatory carbon emissions trading scheme, the EU-ETS has moved from the first to the second phase. New regulations and allocation criteria have been implemented to increase market liquidity and by extension help achieve the EU's Kyoto greenhouse gases reduction target of 8% below 1990 levels. This is the first study to analyse liquidity effects on the EUA futures contracts with respect to key events and daily evolution of transaction volumes in Phase II.

Although the EU-ETS remains the largest carbon trading scheme in the world, it is by no means a finished article; it is troubled by threats of abuses akin to conventional financial markets (see Capoor and Ambrosi, 2009; Kossoy and Ambrosi, 2010; Linacre et al., 2011; Diaz-Rainey et al., 2011). The European Commission and the EU Council and Parliament are continuously drafting new policies in response to the current operational issues arising from the activities on the various platforms. It is currently responding to hacking threats that saw more than €45 million worth of emissions permits stolen from some of the national registries in January 2011 (see Linacre et al., 2011). This event in itself underscores the increasing value of the EU-ETS since fraudsters will only steal valuable items.

The findings made in this chapter suggest that the liquidity of EUA futures contracts is significantly enhanced when they are traded in Phase II of the EU-ETS. As the increase in liquidity spans over a 90 trading day period after the commencement of Phase II, it is suggested that there is a long-term improvement in the liquidity of the trading of carbon permits once they are traded in Phase II of the EU-ETS. This is underscored by the fact that the tested contract, the Dec-2008 EEX EUA futures contract was traded in both Phase I and Phase II of the EU-ETS. The noted liquidity improvements are may be due to the regulatory changes and tighter emission caps introduced for trading in Phase II. The fact that the Phase II is the Kyoto commitment period, when the EU is legally bound to meet reduction obligations, may have contributed to the observed improvements in market quality. The caps are thus tighter, resulting in rising scarcity of permits and may have been associated with improving trades volumes even on largely illiquid carbon platforms such as the EEX.

The rising trades' volume does not necessarily imply improvements in liquidity; instead structural changes such as allowing banking of permits contribute to market confidence. Participants are more willing to trade, safe in the knowledge that the permits can be submitted for compliance purposes in the next phase (Phase III). This potentially promotes a decrease in direct trading costs and asymmetric information costs of trading (see Frino et al., 2010). Positive news on emissions verification exercises may also contribute to growing market confidence in the EU-ETS as shown by results from analysis of impacts of emissions verification results announcements in 2008 and 2009.

Evidence that the introduction of (EC) No 994/2008 of 8 October 2008 is associated with substantial decrease of market liquidity is also reported in this chapter. The loss of liquidity on the short-term may be due to loss of market confidence stemming from fear of insecurity at the national registries since the policy acknowledges the inadequacy of the platforms with respect to security. The policy implication is that there is a need for policy makers to ensure adequate sensitisation of market participants prior to introducing new regulations. The results show that on the long term, market liquidity is restored, thus indicating that participants altered their belief about the state of market security.

Overall, the evidence from this chapter implies that, once the caps are reliably set, uncertainty removed, and trading continuity assured, a mandatory emissions trading scheme such as the EU-ETS has the potential to be successful at reducing carbon emissions. In view of the recent developments in New Zealand and Australia, the success of the EU-ETS could provide a platform for the introduction of a global mandatory market led approach to reducing carbon emissions. Given the paucity of literature on the liquidity of the EU-ETS and the importance of global warming in the world, the findings in this study can be valuable in the future design and regulation of emission trading schemes.

## **5. Summary and Policy Recommendations**

This chapter provides a summary of the results and conclusions from the three empirical studies reported in chapters 2, 3 and 4, as well as the market review of the EU-ETS discussed in Chapter 1. In doing this, I highlight the key contributions of this thesis to the literature on financial markets microstructure and environmental finance. In this chapter, I also make some recommendations for policy.

This body of work provides insights into the market microstructure of the European emissions permit market. It represents the most comprehensive empirical analyses of the EU-ETS market microstructure to date. In three broad chapters, I present empirical evidence on liquidity effects of market events, price discovery (during trading and after hours), market efficiency and determinants of block trade price impact. I employ high frequency intraday data from the world's largest emissions platform, the European Climate Exchange, London; daily data from the largest energy exchange in Europe, European Energy Exchange, Leipzig and daily index data from the London Energy Brokers Association, London.

### **5.1. Summary of Findings**

#### **5.1.1. Phase-Dependent Issues**

Chapter 1 sets the background for this doctoral thesis by briefly reviewing the case for climate change policy. The possible impacts of climate change events on populations across the world are varied depending on geographical location. The fact however remains that there are potential impacts for all parts of the planet. The developing and third world nations face the most dire straits. Australia has the largest exposure in the developed world. There are financial costs to climate change impact. Several studies and reports have documented potential loss of productivity as a result of climatic upheavals (see as examples Kumar and Parikh, 2001; Stern, 2006; Garnaut, 2008).

The anticipated effects of climate change will be felt hardest in the developing and underdeveloped parts of the globe. This seems rather unfair, since it is developed countries that have until now been largely responsible for the current stock of



greenhouse gases in the atmosphere (however, in recent years a developing economy, China, has become the largest global emitter of greenhouse gases). This failure of market economics has so far informed the UN plans of action to combat climate change. The Kyoto Protocol is to date the most ambitious of such plans and requires major contributions from the industrialised world. The Kyoto Protocol allows for flexible market based mechanisms to stabilise the concentration of greenhouse gases in the atmosphere. One of the mechanisms, Clean Development Mechanism (CDM), provides for transfer of low carbon technology to the developing world with the aim of ensuring that those nations transit to low carbon economies without sacrificing growth prospects. The main mechanism of the Kyoto Protocol is International Emissions Trading (IET). Under its EU-ETS programme, the EU has adopted its provisions. The EU opted to have a pre-Kyoto commitment trading period; this provided the regulators a good opportunity to examine possible pitfalls of the system prior to the Kyoto commitment phase. The so-called Phase I served up a lot in terms of structural and operational issues, a number of these are briefly discussed in chapter 1. A major issue affecting market quality is the mode of emissions permits allocation. This is a point on which a significant proportion of academics agree. The regulators opted to grandfather permits in the pre-Kyoto commitment phase, the so-called Phase I, this despite the studies advising against the move (see for example Grubb and Neuhoff, 2006; Neuhoff et al., 2006).

Politically, the use of grandfathering had a general appeal as it helped calm the industries affected and made them more receptive to the policy. The allocation approach however proved to be ill advised. Most of the trading platforms suffered from liquidity risk as the market lacked the much needed level of quality during the Phase I. Phase II; the actual Kyoto commitment period provided an opportunity to reverse some of the losses in Phase I. For Phase II, a combination of grandfathering and auctioning were introduced along with several other measures aimed at improving market quality. These new measures include the permission of inter-phase banking. Inter-phase banking is a much needed change since the non-banking approach adopted in Phase I led to loss of market value for futures contracts with December 2007 expiry. The impact of the new measures on trading quality forms the basis of the empirical investigation in chapter 4.

### 5.1.2. Price Discovery and Trading After-hours on the ECX

With the foregoing review as background, the first empirical investigation of this thesis investigates the intraday evolution of price discovery and market trading efficiency in the EU-ETS. This is a major gap in the current literature on the EU-ETS. The importance of understanding the intraday trading pattern cannot be overemphasised in developing trading strategies for carbon fund managers and compliance traders. For this study, I use tick data from the ECX platform provided by ICE Data LLP, London.

The investigation is predicated on the distribution of information revelation across the entirety of intraday trading periods. In chapter 2, I focus initially on identifying the distribution of information asymmetry across the periods. The Huang and Stoll (1997) spread decomposition model, which is based on portfolio trading pressure, is employed to estimate the bid-ask spread components of the trades over different intraday trading periods. The WPC measure is then used in computing price discovery across different time periods. The WPC is also estimated per trade across the periods. Finally, analogous to Fama (1970), the efficiency of the market is inferred from the efficiency of the price discovery process. To obtain this, I estimate what Biais et al. (1999) call unbiasedness regressions. The regression technique has also been employed by a number of studies (for example Barclay and Hendershott, 2003).

The estimation of the spread decomposition model shows that information asymmetry during the trading day is highest during the first hours of the day and it gradually reduces until the end of the trading day. The after-hours period holds the largest per-hour levels of information asymmetry for all futures contracts examined. This supports the hypothesis that the after hours market is dominated by informed traders. The effective half spread estimates obtained from the model estimation lends credibility to this suggestion. This is due to the fact that spreads widen in response to the presence of more informed traders. The estimates show a dramatic widening of spreads after market closes and this indicates that liquidity suppliers are wary of trading at that time. If liquidity suppliers decide to trade, they must do so with wide enough spreads to cover adverse selection costs. The next set of results (from computing of WPC estimates) indicates an anticipated relationship of price discovery

with information asymmetry and trading activity. The contracts with lower trading volumes contribute higher proportion of price discovery and are responsible for higher levels of information asymmetry. The two lowest trading volume contracts account for approximately 86% of price discovery. The WPCT estimates obtained are consistent with the WPC estimates.

The unbiasedness regressions are used to measure the level of noise in the trading process, estimates suggest that price discovery in the after hours market is less noisy and therefore more efficient than during the normal trading day. The preponderance of less informed traders during the normal trading day means prices are more subject to reversals than during the after hours session. This price reversals and price input errors are responsible for the relative higher level of noise trades in the normal trading day. Although the normal trading day records a higher number of trades per minute than the after market closes period, it records a lower proportion of Euro volume of trades per minute than the after market closes period. And since, efficiency of pricing depends on trading volume, especially in thin markets (see Ciccotello and Hatheway, 2000; Barclay and Hendershott, 2003), prices are very likely to be noisier during the normal trading day *ceteris paribus*. The level of aggregate price efficiency for both periods however compares favourably for the most part (especially for the after market closes period) with equity markets investigated by earlier studies. The general body of results obtained in chapter 2 suggests that the ECX is informationally efficient and its maturity is at a satisfactory level.

### **5.1.3. Price Impact of Block Trades on the ECX**

In recent times, block trades (sometimes referred to as institutional trades) have dominated trading in terms of dollar volume in many markets. Maturity in the EU-ETS may eventually result in more large institutional investments as confidence in the market continues to grow. Chapter 3 of this thesis presents an early study, which is conducted to evaluate properties of determinants of block trade price impact on the largest trading platform in the EU-ETS.

There is a big collection of contributions to the block trades price impact literature, although these are mainly empirical contributions for equity platforms (see for

example Kraus and Stoll, 1972; Holthausen et al., 1987; Holthausen et al., 1990; Gemmill, 1996 among others). Analogous to Holthausen et al. (1990) and Gemmill (1996), I investigate three types of price impacts of block trades: total; temporary; and permanent price impacts. Six explanatory variables are identified: trade volume (natural logarithm); return volatility; and turnover (computed as the natural logarithm of total Euro value of trades on the day prior to the block trade divided by the prevailing Euro volume of open interest). Others determinants employed are: momentum (lagged cumulative daily return on five days prior to block trade); bid-ask spread (prevailing bid-ask spread at trade execution); and market return (contract specific daily return on each EUA futures contract). The study is extended by testing for time of day effects, trade sign effects, and effects of size of block trades.

The results of this study mostly show a divergence from impact of determinants of block trades documented on equity markets. These include the surprising findings that widening spreads are associated with lower price impact of block trades; and that block trades which are executed in the middle of the trading day induce higher price impact than the first or last hours of the trading day. However, this study does uphold the long established price impact asymmetry hypothesis as discussed in sections 3.4 and 3.5.

#### **5.1.4. Liquidity Effects on the EEX**

This study is designed to examine whether or not market quality has improved as a result of the start of trading in Phase II. The motivation for this is clear: market quality improvement over the performance in Phase I is vital to the success of the EU-ETS and by extension the EU's and perhaps global climate change policy. It is expected that the new regime of rules, which are aimed at correcting the deficiencies seen in Phase I would motivate improvements in market quality. Three answers are sought in this process: 1) Did the EEX platform record significant short and/or long-term abnormal returns as a result of onset of trading in Phase II of the EU-ETS; 2) Are there any short and/or aggregate improvements in trading volumes in comparison to a long-term average on EEX platform as a result of onset of trading in Phase II of the EU-ETS; 3) Did the onset of trading in Phase II of the EU-ETS result in any short

and/or long-term liquidity changes on the EEX platform, how do these compare to changes in trading volumes?

Using the process described in Campbell et al. (1997), the first question is investigated by employing an event study and the market model established by Brown and Warner (1985). The results show an interesting pattern, which suggests price improvements (positive abnormal returns) on the short term (-5, +5 days after the start of Phase II trading). The abnormal returns diminish daily from 0.48 on the (-1, +1) window to 0.0002 on the (-5, +5) window. The abnormal return estimates are negative (bordering on 0) on the long-term suggesting that the price appreciations are not only insignificant but are neither permanent. None of the estimates are statistically significant at 5% or 10% levels for the short term, significance borders on 10% levels. Notwithstanding the lack of statistical significance, the results provide some indication of the possible presence of abnormal return on the short term associated with trading in Phase II of the EU-ETS.

The second inquiry is examined in two parts. First, short-term volume changes are evaluated by estimating a dummy variable regression model using dummy variables to represent each of the 11 days in the event window (-5, +5). The estimates are all statistically significant. They indicate that the first two days of trading in Phase II recorded two of three highest trading volumes (2.27 and 2.28 respectively) on average than all other days in the estimated window, and in comparison to aggregate levels of trading 90 trading days prior to the start of trading in Phase II. The estimates decline over the short term to record 1.90, 1.42 and 1.38 for the next three days respectively. The p-value for the Jarque-Bera normality test (0.17) shows that the results are not due to outliers in the sample, the rejection of the null for the presence of unit root (using ADF test statistic) for  $\log(\text{volume})$  also confirms that the variable is stationary. The long-term estimates are analysed by computing the mean and median of the post/pre ratio (+90, -90) of trading volumes in Phase II and using the standard t-statistic to test the null hypothesis that trading volumes are unchanged over the period examined. Results indicate that trading volume has improved in the long-term with the estimates significant at 1% levels. The sustained improvements in trading volumes are symptoms of a maturing and growing market.

The third level of enquiry focuses on liquidity improvements. For this, I compute the ratios of three bid-ask spread measures for (-90) to different short and long term event windows. The bid-ask spread ratios are for quoted, relative and effective bid-ask spread measures. The mean and median for each window is reported. The results, which are all statistically significant, correspond to the volume changes estimates. They indicate liquidity improvements on both the short-term and long-term windows.

The chapter is also extended to test for similar effects based on three other events in Phase II of the EU-ETS: 1) Event 2 is the release of verified emissions retirement data for compliance year 2007 (08/05/2008); 3) Event 3 is the passing of the Commission Regulation (EC) No 994/2008 (Amendment to the Commission regulation (EC) No 2216/2004 of 21 December, 2004) for a standardised and secured system of registries pursuant to Directive 2003/87/EC of the European Parliament and of the Council and Decision No 280/2004/EC of the European Parliament and of the Council (08/10/2008); and 3) Event 4 is the release of verified emissions retirement data for compliance year 2008 (11/05/2009).

None of the three other events tested are also associated with any significant price improvements. They all however appear correlated with varying levels of statistically significant short and long-term improvements in trading volumes. The results of the Jarque-Bera normality test show that the findings are not due to outliers in the sample and the ADF test statistics also confirm that non-stationarity is not of concern in the regression. The divergence comes when testing for liquidity improvements. For Events 2 and 4 (based on release of emission verification results), statistically significant short-term improvements in liquidity are shown to be associated with the events. This is not surprising since the released results reveal that the market was net short for the two compliance periods. The liquidity improvements are not sustained at the same levels for the long term as the spreads progressively widen afterwards. This suggests that the impact of release of emission verification results is not necessarily permanent and eventually fades. For Event 3, which is a corrective operational measure introduced by the EU Commission, temporary loss of liquidity is evidenced suggesting that the regulatory change may have negatively affected market confidence. On the long term, about 60 trading days after the event, I obtain results

showing the gradual recapturing of market liquidity. The results suggest that the loss of market liquidity observed after the legislation is not permanent.

The results show a positive correlation between the new regime of rules, tightened caps and improving market quality, suggesting that the changes are contributory factors to market quality improvements. As is the case on traditional platforms, regulations can also become associated with reducing market confidence as evidenced with the loss of liquidity around the Event 3 period.

## **5.2. Policy implications**

On 8<sup>th</sup> November 2011, Australia, the country with the highest per capita emission levels, enacted legislation for a carbon tax and a compulsory economy-wide emissions trading scheme to commence in 2015. When the scheme commences, Australia will become home to the largest mandatory carbon trading scheme outside of Europe and the second largest in the world. The prospect of a global emissions trading scheme became more likely with Australia coming on board after the EU and New Zealand. By 2015, it is also expected that the Western Climate Initiative (WCI) (which includes California, Ontario, Quebec, Manitoba and British Columbia) and South Korean schemes would be in economy-wide levels of operation. There has also been an indication of a grand alliance of initiatives in the Asia Pacific to include China, Australia, New Zealand, South Korea, Japan, California and parts of Canada. Japan is still committed to its emissions reduction obligations through implementation of its framework for a market-based emission reduction system, the Basic Act on Global Warming Countermeasures (BAGWC).

A major source of concern for climate change proponents remains the United States, the country with the second highest per capita emissions level. Political uncertainty ensures that the Democratic led administration cannot provide global leadership on climate change mitigation through the use of flexible market mechanisms. Further, the current sovereign debt crisis in Europe and the sluggish recovery of the global economy over the past two years have stalled the earlier plans of the Whitehouse to legislate on cap and trade before the next presidential elections in November 2012. In contrast, substantial progress has been made on advancing compulsory emissions

trading at the state level in the United States. Australia's move represents a very important step in keeping alive the possibility of a global emissions trading scheme supported by major economies in the world. When the Australian ETS comes on-stream in 2015, the California state (with the world's ninth largest economy in 2011 when compared with countries of the world) and South Korean versions should be up and running. Along with the EU-ETS and NZ-ETS, these schemes make a powerful statement on the drive to a global trading scheme. Perhaps an equally powerful statement is the landmark move made in Durban, South Africa on 11<sup>th</sup> December 2011 when the 17<sup>th</sup> Conference of Parties (COP) reached a significant climate change deal. The deal ensures continued global commitment to combating climate change.

The view presented above is very optimistic and may in time be proven invalid. New Zealand, Australia, South Korea, California and others may be on the path to emissions reduction through market based measures at this point, but the interest in climate change action in the face of dwindling global economic fortunes has diminished even in those territories. The EU therefore remains the strongest proponent of the continued push towards a truly global climate change action. This is achieved through the EU's key policy tool, the EU-ETS.

The major policy implication arising from the studies reported in this thesis is clear. International emissions trading schemes can work as efficient financial markets with the right combination of factors. The most important factor is the presence of an appropriate regime of rules to ensure sustenance of market confidence. Low transaction costs and diversity of industries involved are also important in maintaining market quality (liquidity and efficient price discovery). If the efficient functioning of the more traditional markets can propagate the creation of wealth, then an efficient ETS can lead to the reduction of greenhouse gases within an emissions constrained economy. The EU-ETS has repeatedly released emission verification results which show net short emissions positions since the Kyoto commitment phase commenced. This is one of the strongest sets of evidence that the scheme achieves its primary purpose. The evidenced smooth functioning of the EU-ETS provides a unique opportunity to build a global platform for climate change action through the international emissions trading mechanism. The challenges associated with achieving a global platform for climate change action are great. The task of aligning the interests



of countries from economically diverse regions and countries at different stages of economic growth to sign up to a global platform of trading emissions will not be easy. It will require huge political capital from policy makers. The significant deal reached in Durban, South Africa therefore comes at a pivotal time. Proponents of climate change action can also point to the successes of the EU-ETS in Phase II as evidenced by this thesis.

The EU has succeeded in forging an international coalition that is committed to reducing global emissions. Although, the existing administrative and legal structures within the EU reduced some of the complexities associated with setting up this coalition, the emission reduction allocation per member country within the EU presents a challenge not unlike the difficulties faced by a truly global alliance to reduce emissions. Moreover, there are three other countries outside of the EU structure that employ the EU-ETS platform as an emissions reduction policy tool namely; Liechtenstein, Norway and Iceland. The successful participation of these three countries (so far) in the EU-ETS underscores the workability of an emissions trading scheme across countries and regions with differing political, administrative and legal structures. Europe continues to point the way forward, but as New Zealand and Australia now formally adopt similar schemes along with provisions urging future linkage with other schemes, we may indeed be closer to a global platform for emissions trading than earlier imagined.

### **5.3. Policy Discussion and Recommendations**

The studies contained in this thesis raise three key issues in terms of policy implications for the EU-ETS.

#### **5.3.1. Design of Regulations**

In section 2.4.4, I demonstrate how the EU Commission's adoption of a new regulation (Commission Regulation (EC) No 994/2008) on 8<sup>th</sup> October 2008 is deemed associated with an incremental loss of market liquidity for approximately three months. This example perhaps demonstrates how new regulation may unnerve a market. A market in its infancy is similar to an economy recovering from an extensive

period of economic recession. New regulations should be carefully modelled to avoid reversing the successes already made. The fact that this change to the rules was introduced just ten months into the Kyoto commitment phase suggests that the Commission's new regime of rules was not adequate. Inadequacies in regulations may lead to loopholes in the market that can be exploited by participants. This scenario creates market uncertainty, which can contribute to loss of market quality. Expectedly, participants would act to protect themselves by withholding trades and liquidity providers will impose wider spreads to protect themselves against informed trading.

Trading on the EU-ETS platforms may easily be withheld for short periods in this market without significantly adversely affecting portfolio fortunes, since emission permits are usually required for submission only once a year by the compliance traders (The temporary halt in trading during January 2011 is a case in point). Carbon fund managers may however need to keep trading to ensure that their portfolios are optimal. The evidence provided by this thesis suggests that just like any other financial market, the EU-ETS does not react positively to uncertainties. The EU-ETS may be maturing quickly but it is still a market in its infancy and must be treated as such. The policy makers must recognise this and act accordingly by showing restraint when new regulations are contemplated mid-way through a trading phase. The anticipated impact of regulations must be modelled before being introduced into the market. This will help in reviewing regulations in such way that they act to forestall unwanted impacts. Ideally, the design of a trading phase should incorporate all necessary regulations.

### **5.3.2. Financial Regulation of the EU-ETS**

In chapter 1, I draw attention to the issue of regulation of carbon markets and how the ambiguity in responsible agencies may contribute to regulatory confusion and to the introduction of regulations with counter-productive effects. The regulation of EUAs (spot trading) is within the remit of the EU Commission and the respective member countries create EUAs as records on national registries. In the EU-ETS and indeed most commodity markets, trading in derivatives outstrip spot trading. It is therefore interesting that the regulation of the carbon permits derivatives with EUAs and CERs

as underlyings is within the remit of different agencies depending on the country where the platform is located. For example, in the UK, the FSA oversees the carbon financial instruments traded on the world's largest platform, the ECX. The current layout of regulations creates an ambiguity that can potentially affect the operation of the market. There needs to be a re-ordering of the financial regulation of the market. It is strongly recommended that an independent EU-wide authority be given sole authority to regulate the EU-ETS with no recourse to local financial authorities. A market in its infancy requires clear signals as to the intentions of the regulators and when those signals emanate from a myriad of sources at different or undefined levels of authority; this may result in uncertainty and ultimate loss of market quality.

The release of the first set of emission verification results in Phase I of the EU-ETS demonstrates the importance of a unified regulatory framework (see Frino et al., 2010; Daskalakis et al., 2011 for discussions on this). The leaking of verification data from national authorities' sources prior to the announcements being made by the EC results in information asymmetry in the market. Information asymmetry harms market confidence and forces market participants into adopting trading strategies that are capable of undermining the goal of the EU-ETS-to reduce emissions.

In view of these issues, policy makers must devise a unified framework for overseeing the operations and regulation of the EU-ETS. This structure should be in the form of a governing entity that can be likened to the European Central Bank. The entity should be granted legal authority to ensure the sustenance of market quality and members should be appointed strictly on merit with no recourse to political expediency. The creation of a single authority overseeing compliance with market regulations would be a good starting point. As the market gains in complexity and sophistication, there would be a need for more specialisation of regulatory framework at the EU level. It is likely that this would lead to the creation of more agencies with clearly defined functions. The market at this nascent stage will benefit from a unified structure. Irrespective of the success in Durban, global action on climate change remains an uncertain prospect and it would benefit from more EU-ETS stability with respect to regulations.

### 5.3.3. Allocation in Phase III

The EC has resolved to advance auctioning of EUAs in Phase III. Phase III will also be the first phase where EUAs from an earlier phase can be submitted towards emissions by participating installations. A careful approach to allocation must be employed to ensure that over-allocation does not occur as it did during the Phase I. If a complete control of the process is not achieved, the EU-ETS in Phase III may suffer from excess liquidity. However, this is unlikely to affect the scheme right from the start of the phase. As pointed out by Benz et al. (2010), the price signal for the market at the start of Phase III will likely be the price at the end of Phase II. As shown in chapter 2, the highest trading exchange-traded futures contract in the EU-ETS for 2009 display a price discovery efficiency that is comparable to more sophisticated asset classes. Beyond the start of the phase however, the market regulators must design an auction system able to deploy under assumption of an imperfect market for EUA spot trading.

Specifically, the auction design should ensure that its price signalling impact adequately reflects the level of emissions permit scarcity in the market and maintain the level of informational efficiency in Phase II. The consideration of scarcity of permits should include the possibility of carbon leakage and cognisance of the use of project based permits such as ERUs and CERs for submissions in lieu of emission abatement by participating installations. Allocation of permits through auctions should also ensure that allocations are made to firms that display the most need for them through a willingness to purchase at competitive prices. The price signalling effect of this is also vital for an efficient ETS. The fact that banking is now allowed in the EU-ETS can lead to installations buying and storing allowances while they have no immediate need for them. The possibility that these could be dumped on the market at some point in the future raises the spectre of price crash induced by excess liquidity.

Perhaps the most important consideration in the design of an auctioning system is that of integrity of the process. If the process is fair and well regarded by all stakeholders, there is likely to be a high level of participating bidders. Transaction costs can be significantly reduced if the process is made transparent and simple, such that complex

bidding strategies aimed at conferring advantage of market power on a few can be avoided (see also Benz et al., 2010).

#### **5.4. Limitations**

Chapter 2 provides an important insight into variations of price discovery over the normal trading hours on the ECX, the world's largest carbon exchange. The study does not, however, resolve the question of whether or not the large differences in intraday evolution of price discovery is as a result of peculiarities on the platform based on its mechanism or actually the divergence in trades' core characteristics over the day. This will be difficult to ascertain given the paucity of required intraday microstructure data. The ECX is the only platform with the minimum amount of transaction volumes required to adequately estimate intraday price discovery and price efficiency. With the current improvements in the EU-ETS, and the possibility of links being created with other emissions trading schemes from other regions, researchers should be able to access the significant amounts of trading data to estimate these parameters in the future. Currently, the ECX is the only platform offering such after hours operations. The impact of this has been shown to be quite significant in the price discovery process. To empirically examine platform dissimilarities, after hours trading data on comparative platforms will be required.

Another limitation can be found in chapter 3. The computation of the three dependent variables employed in the study is carried out using transaction prices in the absence of contemporaneous quotes. Bessembinder (2003) and Peterson and Sirri (2002) suggest that execution cost valuation is least biased when computed using contemporaneous quotes. The use of contemporaneous quotes rather than transaction prices is therefore ideal for limiting bias. The available dataset does not contain these quotes, hence could not be used in this study. However, Alzahrani et al. (2010), among others, also employ transaction prices with robust findings. Further, the predictive power of the ECX dataset used offsets the limitation of variable choice.

## **5.5. Suggestions for Future Research**

In this thesis, I explore two key microstructure issues: market liquidity; and price discovery. An informationally efficient price discovery process is an indicator of market efficiency (Fama, 1970). The measurement of intraday evolution of price discovery efficiency in chapter 2 indicates the efficiency of the ECX as an emissions trading platform. I take the view that the realisation of market efficiency and liquidity at appreciable levels imply market quality. I have presented evidence on the realisation of both in the EU-ETS. Further research relating both concepts over time is therefore needed. There is an increasing amount of literature on the relationship of liquidity and efficiency, but the focus of these studies is on equity markets (see thesis introduction for a detailed discussion). It is my opinion that understanding the relatedness of these two concepts on an unusual market such as the EU-ETS should be of critical academic interest. Chordia et al. (2008) show that short-horizon returns predictability from order flows serves as inverse measure of market efficiency. They provide evidence that narrow spreads (liquidity) on the NYSE correlates unconditionally with reductions in this predictability. Chung and Hrazdil (2010) also report similar results in a large sample study of NASDAQ stocks. Further research should investigate the existence of this level of predictability on EU-ETS platforms, such as the ECX, and try to find the correlation of this with liquidity over time rather than focus solely on intraday evolution. The impact of tick sizes and phase dependencies should also be investigated. Several policy implications feeding into policy formulation may arise in the process. The results will also potentially influence trading strategies on the EU's emissions trading platforms as well as those of other countries and regions around the world.

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