Execution costs in money and futures markets

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CERTIFICATE

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that the thesis has been written by me and that any help that I have received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Signature of Candidate

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Jennifer Kruk

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Preface

Some of the work presented in this thesis has been published as joint work in refereed journals.

Some results from **Chapter 3** have been published as:

> Frino, A., J. Kruk, and A. Lepone, 2007, Price behaviour surrounding block transactions in stock index futures markets: International evidence, *International Finance Review,* Vol. 8.

Some results from **Chapter 4** have been published as:

> Frino, A., J. Kruk, and A. Lepone, 2007, Transactions in futures markets: Informed or uninformed?, *The Journal of Futures Markets* 27, 1159-1174.

Some results from **Chapter 6** have been accepted for publication as:

> Frino, A., J. Kruk, and A. Lepone, 2009, Liquidity and transaction costs in the European carbon futures market, *The Journal of Derivatives and Hedge Funds.*

Synopsis

This dissertation examines the implicit cost of trading in money and futures markets. The research provides empirical evidence on several issues of significance to the growing number of institutional investors in these markets. I address four unique research questions with scarce or conflicting prior research findings. The empirical evidence presented in this dissertation can be used by researchers, investors, and regulators to understand and manage the cost of trading in money and futures markets.

The first issue examined in this dissertation is the price impact of block trades in futures markets. The study examines 14 stock index futures contracts in 11 different international markets and finds that on balance, part of the initial price movement associated with a block trade is temporary. This suggests block trades in futures markets incur a liquidity premium. The study also finds strong evidence that large buyer- and seller-initiated trades have permanent effects on prices, implying they convey information. The study concludes, similar to research based on equity markets, that traders in futures markets are informed.

The second issue examined is an inconsistency in the literature regarding institutional transactions in futures markets. One strand of the literature documents that single trades in futures markets contain information, while another strand finds trade packages in futures markets do not contain information. The second study in this dissertation controls for methodological and sample differences in examining the price impact of individual trades and trade packages, and finds little evidence that transactions in futures markets contain information.

The third issue examined in this dissertation is the anomalous negative relation between execution costs and trade size in opaque markets. Prior literature attributes this relation to information asymmetry and broker-client relationships; however, previous empirical studies are unable to analyse these contributing factors individually. The study addresses this issue by empirically examining the effect of each factor on execution costs in Australian money markets. Results imply that a trader's *ex ante* price information and the relationship a trader has with their broker are both significant determinants of a trader's execution costs in an opaque market; however, traders who establish a strong relationship with their broker will achieve a greater reduction in execution costs than traders with *ex ante* price information. The study also finds evidence that trade size has little explanatory power after controlling for a trader's *ex ante* price information and broker-client relationships.

There is a scarcity of empirical research examining the carbon market – a new and rapidly growing financial market developed to support the trading of carbon emissions. The fourth issue examined in this dissertation is the cost of trading in the largest and most liquid carbon market: the European carbon futures market. Results from prior studies of transaction costs are not necessarily applicable to carbon futures, given the unique features of carbon futures contracts and the immaturity of the carbon market. This study is of interest as it represents the first empirical analysis of liquidity and transaction costs in the carbon futures market. Results from the study imply a substantial increase in liquidity and subsequent reduction in transaction costs as carbon markets mature through time. Unlike traditional futures contracts, where liquidity clusters in quarterly expiry month contracts (March, June, September, December), liquidity in the carbon futures market is concentrated in December expiry month contracts to coincide with annual emissions audits. Further, the study also provides evidence of information asymmetry in carbon futures markets and a permanent price adjustment following medium and large trades.

Chapter 1

Introduction

Institutions that trade in securities markets incur three types of transaction costs – explicit costs, implicit costs, and missed opportunity costs. This dissertation focuses specifically on the implicit cost of trading in securities markets by examining stock index futures, interest rate futures, carbon futures, and money market instruments.

Futures markets are an integral part of the global financial system as they facilitate risk transfer and provide a venue for forward price discovery. Institutional investors dominate trading in futures markets, attracted by high levels of liquidity and relatively low transaction costs. Turnover on the Sydney Futures Exchange during the 2008 Financial Year was approximately 40 trillion dollars, 25 times greater than the 1.6 trillion dollars of turnover on the Australian Stock Exchange over the same period. Despite their significant liquidity, few studies empirically examine the implicit cost of trading in futures markets and those that do document inconsistent results. The central conflict in the literature concerns the information content of trades in futures markets.

The recent global credit crisis highlights the importance of the money market as a facility for banks and institutions to obtain short-term funding. As a result of the credit crisis, money markets around the world effectively shut down, with severe ramifications for global credit availability. If short-term funding is not available at a reasonable price (and hence without incurring substantial costs), banks reduce their lending capabilities and pass on the increased costs to their customers. Turnover in the Australian money market for Bank Accepted Bills (BABs) and Negotiable Certificates of Deposit (NCDs) during the 2008 Financial Year was approximately 4.6 trillion dollars. Despite the importance of money markets, previous studies of opaque markets focus on the implicit cost of trading in corporate and municipal bond markets. No prior literature examines execution costs in the money market.

1.1 Price behaviour surrounding block transactions in stock index futures markets: International evidence

The market impact cost of a trade (price impact) is the difference between the price associated with the execution of a trade and the price that would have prevailed had the trade not executed (Domowitz, Glen, and Madhavan, 2001). Price impact is an implicit cost of trading in securities markets and consists of two components: a temporary liquidity effect and a permanent information effect.[1] Chapter 3 of this dissertation examines price behaviour surrounding

[1] Scholes (1972) and Kraus and Stoll (1972) both originally discuss the components of price impact in equity markets.

block transactions in stock index futures, with a specific focus on the permanent price effect.

Numerous equity market studies analyse the impact of block trades on stock prices.[2] These studies examine two important issues. First, they examine whether temporary and/or permanent price effects are associated with the execution of block trades. A temporary price effect (price reversal) occurs when the stock price moves momentarily due to short-run liquidity costs. A permanent price effect (price continuation) occurs when there is a change in the fundamental value of a stock and its price permanently moves to a new level. Equity market studies provide evidence that block trades have statistically significant permanent price effects, suggesting they are executed by informed traders and contain information. Second, equity market studies examine asymmetries in price behaviour between buys and sells, finding evidence of price continuations following block buys and partial price reversals following block sells. This suggests that in equities markets, sellers pay a liquidity premium while buyers do not.

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[2] Equity market studies examining the price impact of institutional trades include Kraus and Stoll (1972), Dann, Mayers, and Rabb (1977), Holthausen, Leftwich, and Mayers (1987, 1990), Ball and Finn (1989), Reinganum (1990), Choe, McInish, and Wood (1991), Blume and Goldstein (1992), Kumar, Sarin, and Shastri (1992), Chan and Lakonishok (1993, 1995, 1997), Keim and Madhavan (1995, 1996, 1997), Korthare and Laux (1995), Aitken and Frino (1996a, 1996b), Bessembinder and Kaufman (1996), Huang and Stoll (1996), Gemmill (1996), Madhavan and Cheng (1997), Bonser-Neal, Linnan, and Neal (1999), Domowitz, Glen, and Madhavan (2001), Jones and Lipson (2001), Saar (2001), Conrad, Johnson, and Wahal (2001), Nimalendran and Petrella (2003), Bortoli, Frino, and Jarnecic (2004), Chiyachantana, Jain, Jiang, and Wood (2004), Frino, Jarnecic, Johnstone, and Lepone (2005), and Frino, Jarnecic, and Lepone (2007).

There is a dearth of empirical research examining the price behaviour surrounding block trades in futures markets. In contrast to the numerous empirical studies in equities markets, only Berkman, Brailsford, and Frino (2005) explicitly examine the price impact of large block trades in futures markets. The price behaviour surrounding trading in futures markets is expected to differ from equity markets. Subrahmanyam (1991) proposes that index products reduce information asymmetries and encourage liquidity trading as they diversify away any stock-specific information. Compared with underlying equity products, the probability that trades in stock index futures contain information is lower. Chan and Lakonishok (1993) suggest restrictions on short selling in equities markets generate asymmetrical price behaviour in buys and sells. This implies buys and sells should behave symmetrically in futures markets, as there are no short selling restrictions. Berkman et al. (2005) test both of these issues using a sample FTSE 100 stock index futures traded on the London International Financial Futures and Options Exchange (LIFFE). They provide evidence of significant price reversals (i.e. liquidity effects) for large trades, but no evidence of asymmetrical price effects between buys and sells.

The analysis in Berkman et al. (2005) is limited to a single stock index futures contract traded on LIFFE: an electronic order-driven market with an off-market facility to trade blocks greater than 750 contracts.[3] Underlying index

[3] Madhavan and Cheng (1997) find that upstairs markets are primarily used by traders able to credibly signal that their trades are *not* information-motivated. This could result in unique

stocks trade on the London Stock Exchange (LSE) in an electronic order-driven market that interacts with a network of dealers. Further, the sample used in Berkman et al. (2005) covers two relatively short time periods and includes the beginning of the dot com crash, with average daily returns of -0.13 per cent in the first data period and -0.26 per cent in the second data period (Berkman et al., 2005, p567).

Chapter 3 of this dissertation contributes to the literature by extending Berkman et al. (2005) in two important ways. First, it examines 14 stock index futures contracts traded on 11 markets with differing market structures. Second, the data period incorporates five years, in contrast to the sample of three months examined by Berkman et al. (2005). Specifically, Chapter 3 (i) measures total, temporary and permanent price effects associated with block trades, (ii) tests for potential asymmetries in the permanent price effect, and (iii) discusses price impact differences across markets.

1.2 Transactions in futures markets: Informed or uninformed?

Chapter 4 of this dissertation also examines price behaviour surrounding transactions in futures markets; however, the chapter focuses specifically on resolving an inconsistency in the literature. Kraus and Stoll's (1972) seminal study examines the price impact of large buyer- and seller-initiated trades in equity markets. They find that block purchases and sales have permanent price

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dynamics in the downstairs market, as large liquidity traders are attracted to the upstairs market where upon negotiation they can receive a better price for their block transaction.

effects, suggesting that they are executed by informed traders and contain information. Chan and Lakonishok (1993) examine individual institutional trades of all sizes and confirm results in prior equity market studies, finding that institutional purchases and sales have permanent price effects.[7] In an extension of their earlier study, Chan and Lakonishok (1995) acknowledge that it is "misleading" to examine price behaviour surrounding individual trades, as institutions break up large orders into sequences of smaller trades to minimise price impact costs. Using the same data set and a research design similar to Chan and Lakonishok (1993), Chan and Lakonishok (1995) examine price behaviour surrounding "trade packages" and confirm that both purchases and sales have information effects.[8]

There is conflicting evidence in the literature regarding the price impact of trades in futures markets. Berkman, Brailsford, and Frino (2005) examine the price impact incurred by *single* trades on LIFFE.[9] They find that overall purchases and sales have a small, statistically significant permanent (i.e. information) effect. Kurov (2005) estimates the cumulative average returns surrounding single trades on the Chicago Mercantile Exchange (CME) and finds that after a trade occurs, prices move to a new level that is sustained for

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[7] Their data set contains both trade directions (buy or sell) and the identity of the initiating institution.

[8] Trade packages are defined as consecutive purchases (sales) by an institution in one stock, ending when the institution stays out of the market for more than five days.

[9] Berkman et al. examine the price impact for the FTSE 100 stock index futures contract.

at least 30 ticks.[10] These studies provide evidence that institutional trades in futures markets contain information. In contrast, Frino and Oetomo (2005) examine the price impact incurred by trade *packages* on the Sydney Futures Exchange (SFE) and conclude that buy and sell trade packages do not have a permanent effect on price and, therefore, contain no information.

Numerous methodological and sample differences arise when comparing Berkman et al. (2005) and Kurov (2005) with Frino and Oetomo (2005). These methodological and sample differences are a potential cause of the conflicting results discussed above. The most noticeable difference between the studies is that whereas Berkman et al. (2005) and Kurov (2005) examine the price impact associated with single trades, Frino and Oetomo (2005) do so for trade packages. Another significant difference between the studies is the choice of benchmark to measure total, temporary and permanent price effects.[11] Berkman et al. (2005) use an intraday benchmark of mid-quotes five seconds before and five minutes after transactions. Kurov (2005) also conducts an intraday analysis; however, he examines price impact from trade -10 to trade +30 relative to the transaction. Contrasting with both Berkman et al. (2005) and Kurov (2005), Frino and Oetomo (2005) use daily opening and closing prices as benchmarks in their analysis. A further difference between the studies is the specific contract examined. Berkman et al. (2005) examine only

[10] Kurov (2005) examines stock index, currency, and commodity futures. These include S&P 500 futures, Nasdaq-100 futures, Euro futures, Japanese Yen futures, lean hogs, and live cattle.

[11] Chan and Lakonishok (1995) discuss various benchmarks available for use in price impact studies and the potential problems associated with them.

the nearest-to-delivery contract, Kurov (2005) examines the most actively traded contract on the day, and Frino and Oetomo (2005) examine both the nearest-to-delivery and next nearest-to-delivery contracts.[12]

Chapter 4 aims to control for methodological and sample differences in Berkman et al. (2005), Kurov (2005), and Frino and Oetomo (2005) to determine if institutional transactions in futures markets contain information. The analysis uses the same market, sample period, and research design to compare directly the price impact incurred by individual institutional trades and trade packages (consisting of the same individual trades). The primary motivation for Chapter 4 is to resolve the conflicting findings surrounding the information content of institutional transactions in futures markets.

1.3 The determinants of execution costs in opaque markets

Chapter 5 of this dissertation examines the determinants of execution costs in the money market, endeavouring to resolve an inconsistency in the literature. The literature offers two competing explanations for the documented negative relation between execution costs and trade size in opaque markets.[19] One hypothesis, herein referred to as the *price information hypothesis*, suggests

[12] Other methodological differences include the treatment of data around contract expiration and order classification. Additional sample differences include the market analysed, contract type (stock index, interest rate, or commodity), trading mechanism (floor versus electronic) and time period. These are described in detail in Table 2-1.

[19] Studies that document a negative relation between trade size and execution costs include Schultz (2001), Chakravarty and Sarkar (2003), Hong and Warga (2004), Bernhardt, Dvoracek, Hughson, and Werner (2005), Bessembinder, Maxwell, and Venkataraman (2006), Harris and Piwowar (2006), Edwards, Harris, and Piwowar (2007), and Green, Hollifield, and Schühoff (2007a, 2007b).

that institutions actively participating in a market with minimal price transparency obtain an advantage over less active institutions, using their knowledge of market prices to minimise execution costs (Schultz, 2001 and Harris and Piwowar, 2006). The competing hypothesis, herein referred to as the *relationship hypothesis*, suggests that dealers will offer greater price improvements to brokers with whom they have an established relationship (Bernhardt, Dvoracek, Hughson, and Werner, 2005). Both the price information and relationship hypotheses assert that the negative relation between execution costs and trade size arises as large trades are disproportionately executed by institutions with superior price information or brokers with established dealer relationships.

Utilising a unique money market data set, Chapter 5 aims to disentangle the price information and relationship hypotheses and determine their relative effects on execution costs in opaque markets. The analysis presented in Chapter 5 contributes to the literature in several ways. First, it provides evidence that the negative relation between execution costs and trade size documented in corporate and municipal bond markets is also present in the money market. Second, it documents a substantial variation in the magnitude of execution costs incurred by individual traders. This is of particular interest to market regulators, as results imply that irregular traders and those without established broker relationships are placed at a substantial disadvantage in markets with limited price transparency. Third, Chapter 5 provides evidence that the price information and relationship hypotheses coexist; however, traders who establish a relationship with their broker obtain a greater reduction in execution costs than traders with *ex ante* price information.

1.4 Liquidity and transaction costs in the European carbon futures market

Chapter 6 of this dissertation examines the cost of trading in the European carbon futures market. According to World Bank statistics, the European Union Emissions Trading Scheme (EU ETS) dominates the global carbon market. A total of 2,061 million tonnes of carbon dioxide ($MtCO_2$) were traded via the EU ETS in 2007, worth approximately USD 50.39 billion. This represents 97 per cent of total volume and 99 per cent of total value traded on global allowance-based carbon markets in 2007.[21] Futures and forward contracts account for the majority of EU ETS volume and therefore are the focus of Chapter 6. Specifically, the chapter focuses on European Climate Exchange Carbon Financial Instrument (ECX CFI) futures as they represent approximately 80 per cent of exchange traded volume.[22] Futures markets are vital to the EU ETS as they facilitate risk transfer and price discovery, as well as providing a forward curve for the marginal cost of abatement.

ECX CFI futures possess several unique features that differentiate them from traditional futures contracts. First, their underlying asset, a European Union

[21] See The World Bank: State and Trends of the Carbon Market 2008. The EU ETS is described Section 2.3.1.
[22] According to the World Bank, less than two per cent of EU ETS trading occurred on the spot market, and between two and three per cent of trading involved options in 2007.

Allowance (EUA), is a product of legislation.[23] Under the supervision of the European Commission, individual governments are responsible for setting emissions caps and allocating EUAs to firms. In effect, supply and demand in a carbon futures market operates within constraints set by the ruling government, creating a level of political risk not present in traditional futures markets. Second, there is a higher probability of private information in carbon futures markets when compared with traditional futures markets. A select group of employees and auditors have knowledge of a firm's net position in EUAs prior to the market, creating the need for stringent monitoring of insiders. There is also potential for private information at the Member State level, as government employees know their country's net position in EUAs in advance of the market. Third, the most liquid ECX CFI futures contract, the December 2008 contract, traded *without* a spot market for approximately two years.

The combination of these unique contract features and the relative immaturity of the carbon futures market when compared with traditional futures markets suggests that results from previous empirical studies might not directly translate to carbon futures. Chapter 6 of this dissertation explores this issue by conducting the first study of liquidity and transaction costs in the European carbon futures market. Only a handful of studies investigate emissions trading

[23] A European Union Allowance (EUA) gives the holder the right to emit one tonne of carbon dioxide. Each futures contract represents 1,000 EUAs. ECX CFI contract specifications are provided in Chapter 6.

from a financial markets perspective.[24] The common themes among previous financial market studies of emissions trading are carbon pricing, information asymmetry and uncertainty, and market efficiency and price discovery.[25]

1.5 Summary

The four chapters of this dissertation provide evidence regarding the price behaviour surrounding institutional trades in stock index futures, interest rate futures, carbon futures, and money market instruments. Chapters 3 and 6 are motivated by a dearth of empirical research concerning futures block trades and carbon futures markets respectively, while Chapters 4 and 5 are motivated by inconsistencies in the literature.

The remainder of this dissertation is organised as follows. Chapter 2 describes the literature related to each of the above issues and develops several testable hypotheses. Chapters 3, 4, 5, and 6 describe the data and method implemented to test each of the hypotheses outlined in Chapter 2, and report the results from these tests. Conclusions are presented in Chapter 7.

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[24] The dearth of empirical research in this area is surprising. Most research focuses on the spot EUA market, even though it accounts for only two per cent of EU ETS trading volume. Futures markets are underrepresented in the literature.

[25] Studies of carbon pricing include Mansanet-Bataller, Tornero, and Mico (2006), Sijm, Neuhoff, and Chen (2006); Alberola, Chevallier, and Cheze (2007), Convery and Redmond (2007), Daskalakis, Psychoyios, and Markellos (2007), and Daskalakis and Markellos (2007a). Studies of information asymmetry and uncertainty in the European carbon market include (Mansanet-Bataller and Pardo, 2007; Chevallier, Ielpo, and Mercier, 2008). Studies of carbon market efficiency and price discovery include Daskalakis and Markellos (2007b) and Milunovich and Joyeux (2007).

Chapter 2

Literature review

The primary focus of this dissertation is the implicit cost of trading in securities markets, and in particular, price impact. In the literature, any price impact associated with a trade is referred to as the total effect, and consists of two components: a temporary effect and a permanent effect. Previous literature that examines futures markets provides inconsistent evidence regarding the existence of a temporary and/or permanent effect following institutional trades, while in less transparent markets price impact is driven by a trader's *ex ante* price information and the strength of the relationship between trade counterparties. There is no previous literature examining implicit trading costs in the carbon futures market.

A review of the literature concerning these issues occurs in the first three sections of this chapter. Section 2.1 concentrates on literature that documents the price impact of transactions in futures markets, with a particular focus on measurement issues. Section 2.2 focuses on literature that examines execution costs in opaque markets, concentrating specifically on measurement issues and the determinants of execution costs. Section 2.3 evaluates literature relating to the European carbon market. Section 2.4 develops several hypotheses based on the literature reviewed in the first three sections. Section 2.5 summarises and concludes this chapter.

2.1 The price impact of trades in futures markets

This section details the way in which the literature accounts for the price impact of trades in futures markets. The various techniques used for measurement are discussed.

2.1.1 Total, temporary, and permanent price effects

The total price effect measures the overall price impact associated with a trade. That is, it measures the difference between the price associated with the execution of a trade and the price that would have prevailed had the trade not executed (Domowitz et al., 2001).

Scholes (1972) and Kraus and Stoll (1972) originally discuss three reasons for price movements associated with trades – short-run liquidity costs, imperfect substitution among securities, and information. Investors incur short-run liquidity costs when they offer a price concession to entice an unwilling counterparty to participate in the trade. The provision of a price concession results in a temporary deviation away from the equilibrium price, and occurs to compensate the trade counterparty for search, inventory holding, and clearing costs. As securities are not perfect substitutes, the counterparty also requires compensation for partaking in a transaction that is inconsistent with their individual preferences. That is, the long-run expected rate of return on the security must decrease for buyer-initiated trades and increase for seller-initiated trades. Finally, if a trade reveals new information about the equilibrium price of a security, the price of the security will move permanently to a level that reflects its fundamental value. The equilibrium price will remain at this new level until additional information necessitates a further price change.

The total effect consists of two components: a temporary effect and a permanent effect. The temporary effect measures the price reversal associated with a trade. That is, it captures provisional deviations from a security's equilibrium price. Evidence of a temporary effect following a trade suggests that the initial price movement is the result of short-run liquidity costs.[31] The permanent effect measures the change from the pre-trade equilibrium price to the post-trade equilibrium price (Holthausen, Leftwich, and Mayers, 1990). Evidence of a permanent effect following a trade suggests that the initial price movement is the result of information.

Holthausen, Leftwich, and Mayers (1987) discuss the calculation of total, temporary, and permanent price effects in terms of pre-trade and post-trade benchmarks. Equations 2-1 to 2-3 document their calculation of each effect.

$$\textit{Total Price Effect} = \ln\left(\frac{P_t}{P_{Pre}}\right) \qquad (2\text{-}1)$$

$$\textit{Temporary Price Effect} = \ln\left(\frac{P_{Post}}{P_t}\right) \qquad (2\text{-}2)$$

[31] Kraus and Stoll (1972) suggest that the effects of imperfect substitutability between securities are likely to be difficult to observe in a short-run analysis.

$$Permanent\ Price\ Effect = \ln\left(\frac{P_{Post}}{P_{Pre}}\right) \tag{2-3}$$

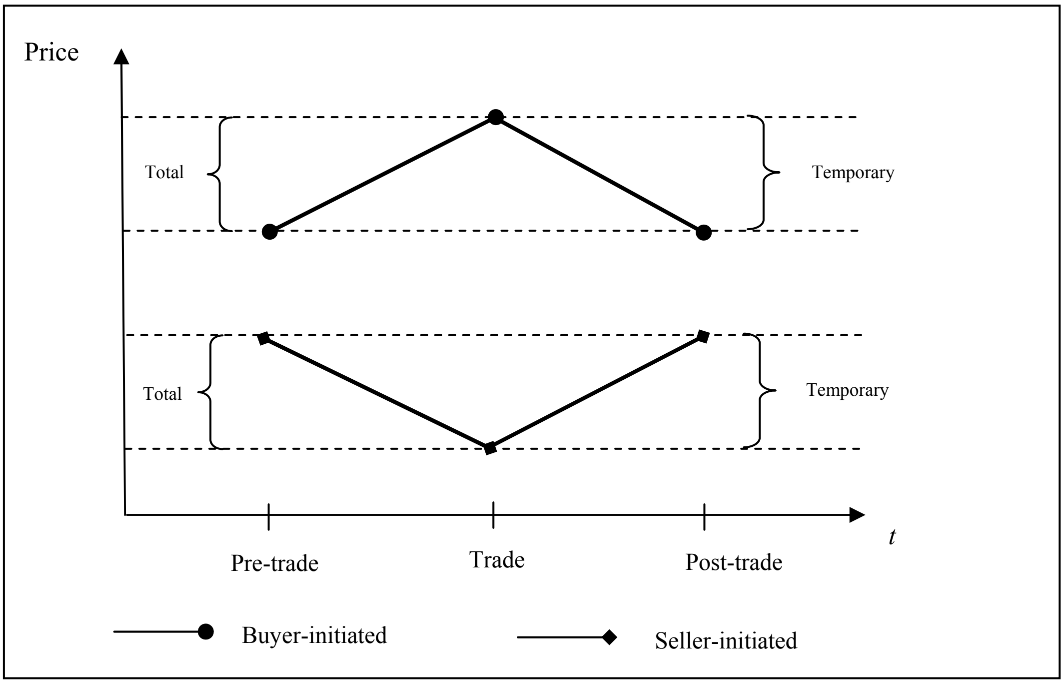
Where P_t is the price of the trade, P_{Pre} is the pre-trade benchmark and P_{Post} is the post-trade benchmark. Section 2.1.3 discusses benchmark selection issues.

Figure 2-1 illustrates the total, temporary, and permanent price effects described in Equations 2-1 to 2-3 under three post-trade price paths – complete price reversal (Panel A), partial price reversal (Panel B), and price continuation (Panel C).

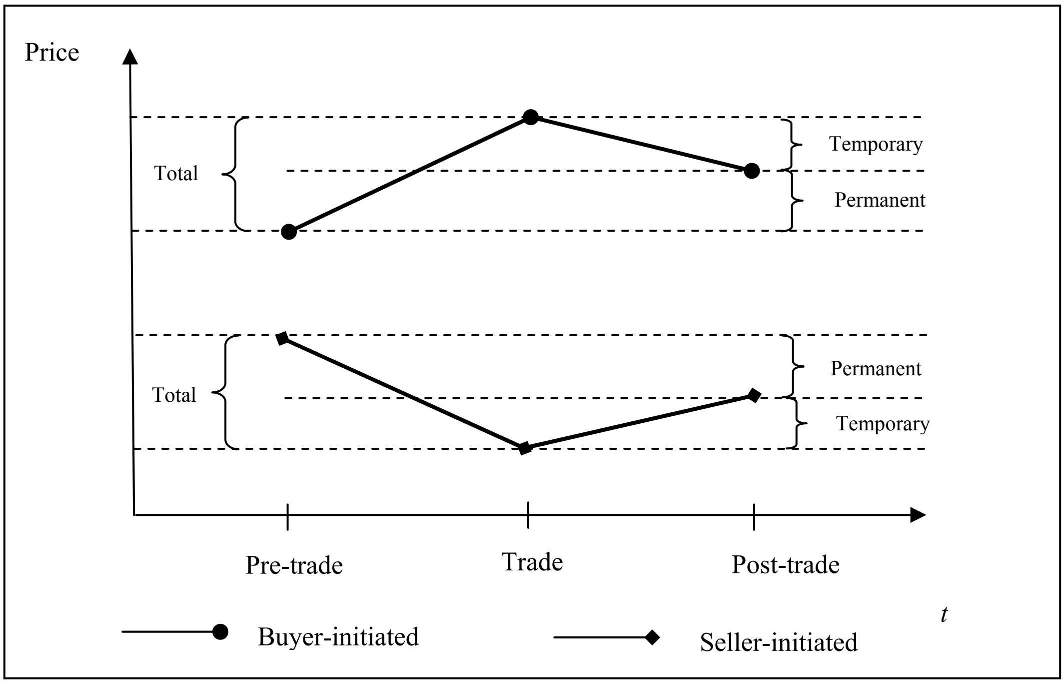
Figure 2-1

Total, temporary, and permanent price effects

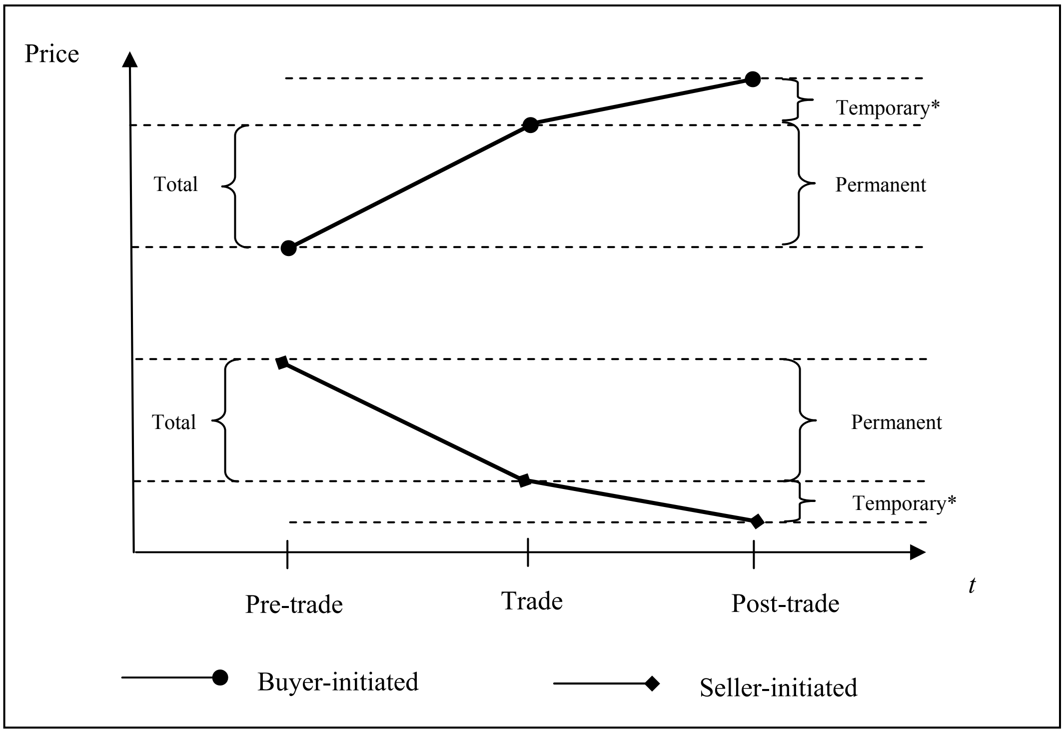
Panel A: Complete price reversal



Panel B: Partial price reversal



Panel C: Price continuation



*This component is referred to as price continuation

Numerous equity market studies analyse total, temporary, and permanent price effects as described in Figure 2-1. These studies examine two important issues. First, they examine whether temporary and/or permanent price effects are associated with the execution of large trades. Second, equity market studies examine asymmetries in price behaviour between buys and sells.

Kraus and Stoll's (1972) seminal study examines the price impact of large buyer- and seller-initiated trades in equity markets, and reports a permanent price effect following block purchases and sales.[33] Other studies that document

[33] In equity market studies, a block trade is generally defined as a trade of 10,000 shares or more, consistent with the block trade definition on the New York Stock Exchange.

a permanent price effect surrounding block trades in equity markets include Holthausen, Leftwich and Mayers (1987, 1990), Chan and Lakonishok (1993, 1995, 1997), Bessembinder and Kaufman (1996), Gemmill (1996), Madhavan and Cheng (1997), Conrad, Johnson and Wahal (2001), Chiyachantana, Jain, Jiang and Wood (2004) and Frino, Jarnecic and Lepone (2007). The overwhelming number of studies documenting a permanent price effect provides evidence that block trades in equity markets are executed by informed traders and contain information.

Despite the considerable evidence supporting the existence of a permanent price effect following equity market block trades, there is conflicting evidence regarding the asymmetrical price behaviour surrounding purchases and sales. Holthausen, Leftwich and Mayers (1987, 1990), Chan and Lakonishok (1993, 1995) and Aitken and Frino (1996a), document a rise in stock prices following block purchases (price continuation) and a partial price reversal following block sales. Conversely, Kraus and Stoll (1972) and Gemmill (1996) document partial price reversals following both block buys and block sells; however, the magnitude of the price reversal is substantially larger for block sells. Chiyachantana et al. (2004) offer a unique perspective on this asymmetry, providing evidence that the underlying market condition (bullish or bearish) is a major determinant of the asymmetry in price behaviour surrounding purchases and sales. They find that purchases have a larger total effect than sales in bullish markets, and sales have a larger total effect in bearish markets.

2.1.2 Evidence from futures markets

Frino and Oetomo (2005) identify three key differences between equity and futures markets that suggest the equity market findings discussed above are not directly applicable to futures markets. First, futures markets are significantly more liquid than equity markets. Second, there is a reduced probability of private information in futures markets. Transactions in futures markets are unlikely to contain information, as informed trades in interest rate contracts require leakage from a central bank (Frino and Oetomo, 2005) and stock index futures diversify away stock-specific information (Subrahmanyam, 1991). Third, unlike equity markets, there are no restrictions on short selling in futures markets. Chan and Lakonishok (1993) suggest the asymmetry between purchases and sales documented in equity markets is a result of short selling restrictions.

Futures markets are an integral part of the financial system as they provide a low cost means of facilitating risk transfer and price discovery (Flemming, Ostdiek, and Whaley, 1996). Despite their importance, only three prior studies examine price impact in futures markets – Frino and Oetomo (2005), Berkman et al. (2005), and Kurov (2005).

Unlike equity markets, there is conflicting evidence in the literature regarding the existence of a permanent effect in futures markets. Berkman et al. (2005) and Kurov (2005) examine the price impact incurred by single trades and find evidence of a permanent effect following purchases and sales.[35] Conversely, Frino and Oetomo (2005) examine the price impact incurred by trade packages and find no evidence of a permanent effect. The following section describes several sample and methodological differences that could contribute to these divergent results.

There is no evidence of asymmetry in the permanent effect in futures markets. Berkman et al. (2005) document no statistically significant difference between purchases and sales in their sample, and attribute this to the absence of short selling restrictions in futures markets. Similarly, Frino and Oetomo (2005) find no evidence of asymmetrical price behaviour surrounding packages of purchases and sales.

2.1.3 Price impact measurement issues

The literature identifies two measurement issues relevant to price impact studies – benchmark selection and split orders (Harris, 2003). Benchmark selection is the choice of pre- and post-trade benchmarks, while split orders occur when investors execute large orders through a series of smaller trades.

Price impact is an implicit cost of trading and hence is not directly observable. To provide an accurate measure of total, temporary, and permanent effects, studies of price impact require careful selection of pre- and post-trade

[35] Berkman et al. (2005) document a small permanent effect across all trades in their sample; however, they do not document a statistically significant permanent effect in their largest trade size group (>100 contracts).

benchmarks.[37] The pre-trade benchmark represents the price that would have prevailed had the trade not executed (Domowitz et al., 2001), while the post-trade benchmark represents the equilibrium price after all short-term price pressure has dissipated (Harris, 2003).

Table 2-1 documents pre-trade benchmarks employed in equity and futures market price impact studies. The most common pre-trade benchmark adopted in the literature is the opening price on the day of the trade (or on the first day of the trade package). Other pre-trade benchmarks include the trade preceding the block trade, an arbitrary number of trades prior to the block trade, and the closing price on the previous day. The choice of pre-trade benchmark is particularly important when investors split their orders into several smaller trades. In the case of split orders, Chan and Lakonishok (1995) and Harris (2003) contend that a pre-trade benchmark that is not independent of the order will bias the total effect downward.

The most common post-trade benchmark documented in Table 2-1 is the closing price on the day of the trade. Other post-trade benchmarks include an arbitrary number of trades after the block trade and the closing price on the following day. Similar to pre-trade benchmarks, the choice of post-trade benchmark is acutely important for split orders. Implementing a post-trade

[37] Equation 2-1, Equation 2-2, Equation 2-3, and Figure 2-1 explain the measurement of total, temporary, and permanent price effects in terms of pre- and post-trade benchmarks.

benchmark that is not independent of the order will bias the permanent effect upward.

The three futures market studies reported in Panel B and Panel C of Table 2-1 employ different pre- and post-trade benchmarks. Berkman et al. (2005) use an intraday benchmark of mid-quotes five seconds before and five minutes after transactions. Kurov (2005) also conducts an intraday analysis; however, he examines price impact from trade -10 to trade +30 relative to the transaction. Contrasting with both Berkman et al. (2005) and Kurov (2005), Frino and Oetomo (2005) use daily opening and closing prices as benchmarks in their analysis.

The literature highlights split orders as a second measurement issue relevant to price impact studies. As investors will break up large orders to minimise price impact, Chan and Lakonishok (1995) suggest that the unit of measurement should be the entire trade package.[38] They define a trade package as consecutive purchases (sales) by an institution in one stock, ending when the institution stays out of the market for more than five days. Panel C of Table 2-1 illustrates the inconsistency in futures market studies regarding split orders. Frino and Oetomo examine trade packages and find no permanent price effect, while Berkman et al. (2005) and Kurov (2005) examine individual trades and document a permanent price effect.

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[38] This argument is analogous to the stealth trading hypothesis in Barclay and Warner (1993) and Chakravarty (2003).

Table 2-1
Literature summary: Price impact in equities and futures markets

This table summarises the methodology and results of several price impact studies. Panel A reports equity market studies, while Panel B and Panel C report futures market studies.

A. Equity market studies	Market	Sample period	Trades analysed	Pre-trade benchmark	Post-trade Benchmark	Temporary / Permanent effect
Kraus and Stoll (1972)	NYSE	1968 –1969	Block Trades	Close price previous day	Close price on day	Buys – Partial reversal Sells – Partial reversal
Holthausen, Leftwich, and Mayers (1987)	NYSE	1982	Block Trades	Trade preceding block trade	Close price on day	Buys – Price continuation Sells – Partial reversal
Holthausen, Leftwich, and Mayers (1990)	NYSE	1982 – 1984	Block Trades	Trade preceding block trade	Close price on day	Buys – Price continuation Sells – Partial reversal
Chan and Lakonishok (1993)	NYSE	1986 – 1988	Institutional Trades	Open price on day	Close price on day	Buys – Price continuation Sells – Partial reversal
Chan and Lakonishok (1995)	NYSE	1986 – 1988	Trade Packages	Open price on first day	Close price on last day	Buys – Price continuation Sells – Partial reversal
Keim and Madhavan (1995)	NYSE	1991 – 1993	Trade Packages	Close price previous day	Close price day after	Buys – Price continuation Sells – Partial reversal
Aitken and Frino (1996a)	ASX	1991 – 1993	Trade Data	Open price on day	Close price on day	Buys – Price continuation Sells – Partial reversal
Aitken and Frino (1996b)	ASX	1991 – 1993	Trade Packages	Open price on day	Close price on day	Buys – Price reversal Sells – Price continuation
Gemmill (1996)	LSE	1987 – 1992	Block Trades	Average trade -3 to trade -5	Average trade +4 to trade +6	Buys – Partial reversal Sells – Partial reversal
Madhavan and Cheng (1997)	NYSE	1993 – 1994	Block Trades	20 trades before block trade	20 trades after block trade	Buys – Partial reversal Sells – Partial reversal
Bonser-Neal, Linnan and Neal (1999)	Jakarta Stock Exchange	1992 – 1995	Block Trades	Open price on day	Close price on day	Buys – Price continuation Sells – Partial reversal

Table 2-1 continued

B. Futures market studies	Market	Sample period	Futures analysed	Contract analysed	Trading mechanism
Frino and Oetomo (2005)	SFE	2000 – 2003	Index, interest rate	Near & Deferred	Electronic
Berkman, Brailsford, and Frino (2005)	LIFFE	2000	Index	Near	Electronic
Kurov (2005)	CME	2000 – 2001	Index, currency, commodity	Most active contract on day	Electronic / Floor

C. Futures market studies	Contract expiration	Order classification	Trades analysed	Pre-trade benchmark	Post-trade benchmark	Temporary / Permanent effect
Frino and Oetomo (2005)	Delete 10 days before Near maturity	Buyer & seller identified in data	Packages	Opening price first day of package	Closing price day after package ends	Buys – Full reversal Sells – Full reversal
Berkman, Brailsford, and Frino (2005)	N/A	Quote-based rule	Single trades	Mid-quote 5 sec before trade	Mid-quote 5 min after trade	Buys – Partial reversal* Sells – Partial reversal*
Kurov (2005)	N/A	Separate records for buys & sells	Single trades	10 ticks before	30 ticks after	Buys – Price continuation Sells – Price continuation

* This result is across all trade size groups. When Berkman, Brailsford, and Frino (2005) examine the largest trade size group (analogous to block trades) they find no evidence of a statistically significant permanent effect.

Panel B of Table 2-1 documents several additional sample differences between Frino and Oetomo (2005), Berkman et al. (2005), and Kurov (2005) that could contribute to the inconsistent results. The data in Frino and Oetomo (2005) encompass electronic trading on the SFE from 2000 to 2003, the data in Berkman et al. (2005) encompass electronic trading on the LIFFE during 2000, while the data in Kurov (2005) encompass electronic and floor trading on the CME from 2000 to 2001. In addition, Frino and Oetomo (2005) examine trades in the near and deferred contracts for stock index and interest rate futures, Berkman et al. (2005) examine trades in the near contract for stock index futures, and Kurov (2005) examines trades in the most active contract on the day for stock index, currency, and commodity futures.

Panel C of Table 2-1 documents two additional methodological discrepancies between futures market studies, including the treatment of trades around contract expiration and order classification. Frino and Oetomo (2005) delete trades that occur within 10 days of expiry of the nearest to delivery contract to account for rollover effects, while Berkman et al. (2005) and Kurov (2005) do not explicitly state how they treat data around contract expiration. In addition, the data utilised in Frino and Oetomo (2005) and Kurov (2005) permit identification of the buy and sell side of each trade, while the data employed in Berkman et al. (2005) do not identify trade direction. Instead, Berkman et al. (2005) employ a quote-based rule to classify trades as buyer- or seller-initiated.

Table 2-1 highlights many methodological and sample differences that exist between Frino and Oetomo (2005), Berkman et al. (2005), and Kurov (2005). These differences are likely to contribute to their inconsistent findings, namely that Berkman et al. (2005) and Kurov (2005) document a permanent price effect in futures markets, while Frino and Oetomo (2005) do not.

2.2 Execution costs in opaque markets

This section details the way in which literature accounts for execution costs in opaque markets. The various techniques used for measurement are discussed, as are the determinants of execution costs.

2.2.1 Execution cost measurement

Measuring execution costs in opaque markets requires a different approach to transparent equity and futures markets. As discussed in Section 2.1, studies in transparent markets implement pre- and post-trade benchmarks to measure execution costs. These benchmarks can include prevailing quotes, opening prices, or closing prices. As pre- and post-trade price transparency is severely limited in opaque markets, different methodology is required. One exception to this is Bernhardt, Dvoracek, Hughson, and Werner's (2005) study of execution costs on the London Stock Exchange (LSE) prior to the commencement of electronic limit order book trading. Bernhardt et al. (2005) utilise data from 1991, when the LSE operated as a dealer market, and were subsequently able to obtain prevailing quotes to measure price improvement.

The illiquidity of corporate and municipal bonds also affects the measurement of execution costs in opaque markets. Nine of the 10 studies described in Table 2-2 examine the corporate or municipal bond market. Harris and Piwowar (2006) report that the majority of municipal bonds in their sample trade less than once per week and Schultz (2001) asserts that corporate bonds also trade infrequently.

The literature adopts three distinct approaches to measuring execution costs in opaque markets when prevailing quotes are unobservable and trading is infrequent. These three approaches are outlined in Table 2-2 and include realised spreads (dealer mark-ups), regression analysis incorporating a trade direction indicator variable, and time-series econometric analysis.

Studies of opaque markets measure realised spreads in two ways – the daily realised spread and dealer mark-ups. The daily realised spread for a given bond is the difference between the mean daily price of all ask-based trades and the mean daily price of all bid-based trades. Dealer mark-ups are the difference between a dealer's sell price and buy price for a specific bond, and are analogous to the execution cost incurred by a customer.[41] Hong and Warga (2000, 2004) and Chakravarty and Sarkar (2003) estimate execution costs as the daily realised spread, while Green, Hollifield, and Schühoff (2007a,

[41] The calculation of dealer mark-ups requires matching of buy and sell bond trades.

2007b) estimate execution costs as dealer mark-ups.[42] Harris and Piwowar (2006) assert that utilising daily realised spreads to measure execution costs is problematic, as it restricts the sample to actively traded bonds.

Regression analysis provides an additional means of calculating execution costs in opaque markets. To conduct the analysis, the difference between the transaction price and a benchmark price is regressed on a buy/sell indicator, where the coefficient of the buy/sell indicator provides an estimate of execution costs. As the benchmark price is not directly observable in an opaque market, Schultz (2001) estimates intraday bid quotes using a three-step procedure that incorporates the percentage price change in a matched Treasury bond. Regression-based methodology mitigates the sample selection bias when using daily realised spreads as it measures execution costs for active and inactive bonds. Both Schultz (2001) and Bessembinder, Maxwell, and Venkataraman (2006) employ regression-based methodology to estimate execution costs.

[42] Green et al. (2007b) calculate mark-ups on new issues of municipal bonds. That is, the difference between the price of the new issue sale and the reoffering price.

Table 2-2
Literature summary: Execution costs in opaque markets

This table summarises the methodology employed to measure execution costs in opaque markets and reports the determinants of execution costs.

Study	Market	Sample period	Execution cost measure(s): Approach	Execution cost measure(s): Calculation	Determinants of execution costs (direction)
Hong and Warga (2000)	US corporate bonds	1995 – 1997	Realised spread	▪ Daily dollar-VWAP transacted at the ask – Daily dollar-VWAP transacted at the bid	▪ Squared bond return in month of transaction (+)
Schultz (2001)	US corporate bonds	1995 – 1997	Regression with trade direction indicator	▪ Estimate intraday bid quote from month-end quotes using a three-step procedure. Regress difference between bid quote and transaction price on a dummy variable that is 1 for buys and 0 for sells.	▪ Active institutions (-) ▪ Active dealer (-) ▪ Trade size (-)
Chakravarty and Sarkar (2003)	US Treasury, corporate & municipal bonds	1995 – 1997	Realised spread	▪ Mean daily sell price – Mean daily buy price	▪ Credit risk (+) ▪ Macroeconomic announcements (+) ▪ Time to maturity (+) ▪ Trade size (-)
Hong and Warga (2004)	US municipal bonds	2000	Realised spread	▪ Mean daily price transacted at the ask – Mean daily price transacted at the bid ▪ DRS also calculated using closest-in-time bid and ask transactions, and closest-in-price bid and ask transactions	▪ Callability (+) ▪ Pre-refunded (-) ▪ Time to maturity (+) ▪ Trade size (-)
Bernhardt, Dvoracek, Hughson, and Werner (2005)	LSE (dealer market)	1991	Price improvement	▪ Best ask – Customer buy price; Customer sell price – Best bid ▪ Price improvement is reported in pence, per cent of the quote midpoint, and per cent of the touch (i.e. quoted spread).	▪ Strength of broker-dealer relationship (+) ▪ Trade size (-) ▪ Trade size after fixing relationship (-) small and med trades (+) large trades

Table 2-2 continued

Study	Market	Sample period	Execution cost measure(s): Approach	Execution cost measure(s): Calculation	Determinants of execution costs (direction)
Bessembinder, Maxwell, and Venkataraman (2006)	US corporate bonds	2002	Regression with trade direction indicator	▪ Regress the bond price change on: three public information variables, surprise order flow, and an indicator variable that is one 1 for customer buys and -1 for customer sells.	▪ Increased bond price transparency (-) ▪ Trade size (-)
Harris and Piwowar (2006)	US municipal bonds	1999 – 2000	Econometric time-series analysis	▪ Obtain the effective half-spread from time-series regressions estimated separately for each bond in the sample.	▪ Bond complexity (+) ▪ Credit risk (+) ▪ Time since issuance (+) ▪ Time to maturity (+) ▪ Trade size (-)
Edwards, Harris, and Piwowar (2007)	US corporate bonds	2003 – 2005	Econometric time-series analysis	▪ Obtain the effective half-spread from time-series regressions estimated separately for each bond in the sample.	▪ Credit risk (+) ▪ Increased bond price transparency (-) ▪ Time since issuance (+) ▪ Time to maturity (+) ▪ Trade size (-)
Green, Hollifield, and Schühoff (2007a)	US municipal bonds	2000 – 2004	Realised spread (dealer mark-up)	▪ Gross dealer mark-up: (Dealer sell price – Dealer buy price) / Dealer buy price ▪ Net dealer mark-up: Gross mark-up – Return on maturity matched municipal index	▪ Trade size (-)
Green, Hollifield, and Schühoff (2007b)	US municipal bonds (new issues)	2000 – 2003	Realised spread (mark-up on new issues)	▪ Gross mark-up: (Price of New Issue Sale – reoffering price) / reoffering price ▪ The reoffering price is the price at which the bonds are sold to the public participating in the primary offering.	▪ Trade size (-)

One final method for calculating execution costs in an opaque market is the time-series econometric analysis pioneered by Harris and Piwowar (2006) and also implemented in Edwards, Harris, and Piwowar (2007). Harris and Piwowar (2006) develop a response function curve that represents average customer execution costs, and estimate their model using iterated weighted least squares. The Harris and Piwowar (2006) model of customer execution costs includes a fixed cost component and a trade size component. As with regression-based analysis, time-series econometric analysis calculates execution costs for both active and inactive bonds.

2.2.2 The determinants of execution costs in opaque markets

The determinants of execution costs described in Table 2-2 fall into three categories – market microstructure, bond-specific, and trade-specific. Market microstructure determinants relate specifically to the availability of pre- and post-trade price information. Bond-specific determinants incorporate characteristics of individual bonds, such as time to maturity and credit risk. Trade-specific determinants encompass characteristics of the trade itself, such as trade size and the institution executing the trade.

Bessembinder et al. (2006) and Edwards et al. (2007) examine the effects of an improvement in post-trade price transparency in the US corporate bond market. From July 1, 2002, the National Association of Securities Dealers (NASD) required public reporting of transactions in approximately 500 corporate bond issues. Both studies document a significant reduction in execution costs following this change, demonstrating that price transparency is a major determinant of execution costs in opaque markets. Interestingly, Bessembinder et al. (2006) also document a reduction in execution costs for bonds not eligible for transaction reporting, providing evidence of a liquidity externality.

Several studies examine bond characteristics as determinants of execution costs and report consistent findings. Chakravarty and Sarkar (2003), Hong and Warga (2004), Harris and Piwowar (2006), and Edwards et al. (2007) document higher execution costs for bonds further away from maturity and bonds with higher credit risk. In addition, Harris and Piwowar (2006) and Edwards et al. (2007) document higher execution costs for older and more complex bonds.[45]

Nine of the 10 studies reported in Table 2-2 examine trade-specific determinants of execution costs. All nine studies assess the explanatory power of trade size, documenting a negative relation between trade size and execution costs. That is, in markets with minimal price transparency, execution costs decrease with trade size. Studies that document this effect encompass several markets, including the US corporate bond market (Schultz, 2001; Chakravarty and Sarkar, 2003; Bessembinder et al., 2006; Edwards et al., 2007), the US municipal bond market (Hong and Warga, 2004; Harris and

[45] Bond complexity incorporates features such whether the bond (i) is callable, (ii) has a sinking fund, (iii) permits special redemption or an extraordinary call, (iv) is credit enhanced, or (v) has a nonstandard interest rate payment frequency.

Piwowar, 2006; Green et al. 2007a, 2007b), and the London dealer market (Bernhardt et al., 2005).[46] The observed negative relation between execution costs and trade size is in contrast to empirical studies of execution costs in transparent equity markets, which provide evidence that execution costs increase with trade size.[47]

Literature offers two competing explanations for the documented negative relation between trade size and execution costs in opaque markets. Each explanation asserts that large trades incur lower execution costs as they are disproportionately executed by a specific group of institutions.

First, Schultz (2001) and Harris and Piwowar (2006) propose that institutions regularly participating in a non-transparent market possess superior knowledge of market prices. Active institutions obtain this price information through their frequent contact with bond market dealers, and are able to use it to minimise their execution costs. Schultz (2001) explicitly tests this hypothesis by comparing execution costs incurred by active and inactive institutions.[48] He regresses execution costs on a dummy variable which categorises 20 institutions by their total dollar volume transacted over a 28-month period. The coefficient of this dummy variable is negative and statistically significant, providing evidence that active institutions incur substantially lower execution

[46] Bessimbinder et al. (2006) document a negative relation between execution costs and trade size for transaction reporting bonds only.
[47] See Kraus and Stoll (1972), Holthausen, Leftwich, and Mayers (1987, 1990), and Chan and Lakonishok (1995).
[48] Harris and Piwowar (2006) are unable to directly test this hypothesis.

costs than inactive institutions.[49] There are several limitations to the classification methodology employed by Schultz (2001). These include (i) the classification of institutions based on their total dollar volume as opposed to their trade frequency, leading to the misclassification of institutions that transact a large dollar volume in a small number of trades as 'active', (ii) classification at the institutional level, thus not accounting for institutions with more than one trader active in the market, and (iii) overlooking the short-lived nature of information in markets, as the methodology classifies traders based on their volume traded across his entire 28-month sample.

Second, Bernhardt et al. (2005) provide evidence that brokers with strong broker-dealer relationships receive greater price improvements from their dealers. They measure the strength of a broker-dealer relationship by the volume transacted between broker and dealer over a 20-day rolling window. Volume estimates include stock-specific volume and volume aggregated across stocks. The coefficient of the stock-specific volume relationship variable is positive and statistically significant for all trade size groups, providing evidence that brokers with strong broker-dealer relationships receive greater price improvements. Bernhardt et al. (2005) also incorporate dealer profits as a proxy for the strength of the broker-dealer relationship. However,

[49] Results are similar when repeated for active and inactive dealers.

their results show that dealer profits are not a good relationship proxy as they are difficult to measure.[50]

Schultz (2001) implements a different method to measure trading relationships, leading to results inconsistent with Bernhardt et al. (2005). He examines a subsample of institutions (those classified as ‘active’) and compares the execution costs of institutions trading with their regular dealer(s) against execution costs of institutions trading with dealers they rarely use. Schultz (2001) finds that the relationship between institution and dealer has no impact on the institution’s execution costs. There are several limitations to the methodology employed by Schultz (2001) to measure trading relationships, namely that it aggregates individual trading relationships at the institutional level and it only examines a subset of active institutions.

Order processing costs provide a potential third explanation for the observed negative relation between execution costs and trade size in opaque markets. Order processing costs are large in an opaque market, as minimal transparency makes searching for price information expensive. Harris and Piwowar (2006) and Edwards et al. (2007) examine the role of order processing costs in opaque markets by explicitly modelling the fixed cost component of their total cost function. Both studies find high fixed costs do not explain the decline in execution costs across all trade sizes.

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[50] Measuring dealer profits requires selection of a post-trade benchmark price to compare with the transaction price.

2.3 Carbon markets in Europe

This section details the way in which the literature examines the European carbon market. The European carbon market is described, as is literature relating to emissions pricing, information asymmetry and uncertainty, and market efficiency and price discovery.

2.3.1 The European Union Emissions Trading Scheme (EU ETS)

The European Commission established the EU ETS as a least cost measure to help Member States achieve their commitments under the Kyoto Protocol. The scheme is divided into three distinct phases. Phase I is the trial phase and includes the years 2005 to 2007, Phase II is the Kyoto period and includes the years 2008 to 2012, and Phase III is the post-Kyoto period and includes the years 2013 to 2020. The industries covered by the scheme include iron, steel, cement, glass, ceramics, pulp, paper, and energy (both electric power generation and refineries). These industries represent 11,500 emission sources and account for almost 50 per cent of all European Union emissions.[57]

The EU ETS is designed as a cap and trade scheme. Prior to the commencement of each phase, Member States submit their annual emissions targets (the cap) to the European Commission for approval. Emissions targets are submitted in a formal document called a National Allocation Plan (NAP). Table 2-3 details emissions caps for Phase II. Once approved, the European Commission requires that Member States allocate European Union

[57] See the European Commission's website for further detail.

Allowances (EUAs) to firms covered by the scheme no later than the end of February each year. One EUA gives the holder the right to emit one tonne of carbon dioxide, and there is a restriction on the number of permits Member States are allowed to auction.[58]

Upon commencement of each phase, firms are able to buy and sell EUAs depending on their individual needs. At the end of each calendar year firms are required to complete an annual report on their emissions and have the report verified by an external auditor. At that point in time, the firm must possess a sufficient number of EUAs to offset their emissions; otherwise they will incur severe financial penalties in addition to their mandatory obligation to cover any shortfall.[59] The penalty for Phase I is 40 euros per missing EUA and for Phase II the penalty is 100 euros per missing EUA. Emissions data for a particular year is published by the European Commission in late April or early May the following year.

[58] The European Commission is gradually phasing out free EUAs. In Phase I, Member States could not auction more than 5 per cent of permits. This cap increased to 10 per cent for Phase II, and thus far it seems likely that 100 per cent of permits for the power generation sector will be auctioned in Phase III.

[59] Firms can also obtain Certified Emissions Reduction (CER) units from investing in greenhouse gas reducing projects through the Clean Development Mechanism. One CER is equal to one EUA; however, there is a cap on the number of CER credits a firm can obtain in place of EUAs.

Table 2-3
Phase II National Allocation Plans for EU Member States

This table reports the National Allocation Plan (NAP) submitted by each Member State to the European Commission (EC) for Phase II of the EU ETS. *Phase I cap* is the EC approved annual carbon dioxide emissions cap during Phase I, *Verified 2005 emissions* are actual carbon dioxide emissions during 2005, *Proposed Phase II cap* is the annual carbon dioxide emissions cap proposed by the Member State for Phase II, and *Allowed Phase II cap* is the annual carbon dioxide emissions cap imposed by the EC. All caps are measured in million tonnes of carbon dioxide ($MtCO_2$). *Proposed vs. Actual* is the percentage difference between the Phase II cap proposed by the Member State and the cap mandated by the EC. Data are sourced from the European Commission.

Member State	Phase I cap	Verified 2005 emissions	Proposed Phase II cap	Allowed Phase II cap	Proposed vs. Actual (%)
Austria	33.0	33.4	32.8	30.7	-6.4
Belgium	62.1	55.6	63.3	58.5	-7.6
Bulgaria	42.3	40.6	67.6	42.3	-37.4
Cyprus	5.7	5.1	7.1	5.5	-23.0
Czech Rep.	97.6	82.5	101.9	86.8	-14.8
Denmark	33.5	26.5	24.5	24.5	0.0
Estonia	19.0	12.6	24.4	12.7	-47.8
Finland	45.5	33.1	39.6	37.6	-5.1
France	156.5	131.3	132.8	132.8	0.0
Germany	499.0	474.0	482.0	453.1	-6.0
Greece	74.4	71.3	75.5	69.1	-8.5
Hungary	31.3	26.0	30.7	26.9	-12.4
Ireland	22.3	22.4	22.6	22.3	-1.3
Italy	223.1	225.5	209	195.8	-6.3
Latvia	4.6	2.9	7.7	3.4	-55.5
Lithuania	12.3	6.6	16.6	8.8	-47.0
Luxembourg	3.4	2.6	4.0	2.5	-36.7
Malta	2.9	2.0	3.0	2.1	-29.1
Netherlands	95.3	80.4	90.4	85.8	-5.1
Poland	239.1	203.1	284.6	208.5	-26.7
Portugal	38.9	36.4	35.9	34.8	-3.1
Romania	74.8	70.8	95.7	75.9	-20.7
Slovakia	30.5	25.2	41.3	30.9	-25.2
Slovenia	8.8	8.7	8.3	8.3	0.0
Spain	174.4	182.9	152.7	152.3	-0.3
Sweden	22.9	19.3	25.2	22.8	-9.5
UK	245.3	242.4	246.2	246.2	0.0
TOTAL	2,298.5	2,122.2	2,325.3	2,080.9	-10.50

As with most financial markets, trading in the EU ETS occurs in the spot market, the forward market (both exchange traded and over-the-counter), and the options market. Approximately 95 per cent of trading in the EU ETS occurs in the forward market, with the remaining five per cent occurring in the spot and options markets.[63] Exchange-based spot market trading is concentrated on Bluenext; however, trading is also available on Climex, the European Climate Exchange, the European Energy Exchange, Energy Exchange Austria, and Nord Pool. Futures trading is concentrated on the European Climate Exchange, which uses the ICE Futures platform to trade its products. Bluenext and the European Energy Exchange also list futures contracts on EUAs.

2.3.2 Carbon emissions pricing

The majority of carbon market empirical studies focus specifically on factors that influence the price of carbon emissions. Table 2-4 summarises the results of these studies, with a particular focus on the determinants of the carbon price. The determinants of the carbon price outlined in Table 2-4 fall into one of three categories – energy prices, weather, and industrial production.

Kanen (2006) asserts that in a carbon market short of allowances, energy prices are the most important determinants of the carbon price. Of particular importance are coal, gas, electricity and oil prices, and dark and spark spreads. A dark spread is the theoretical profit of a coal-fired power plant per unit of

[63] The World Bank: State and Trends of the Carbon Market 2008.

electricity, and is defined as the difference between the power price and the cost of coal to generate 1MWh of electricity. A spark spread is the theoretical profit of a gas-fired power plant per unit of electricity, and is defined analogously. (Kanen, 2006; Alberola, Chevallier, and Chèze, 2008b). Clean dark spreads and clean spark spreads incorporate the cost of carbon emissions into power plant profits.

Coal and gas prices influence the price of carbon emissions through the fuel-switching price. The fuel-switching price is the equilibrium carbon price that equates clean dark spreads with clean spark spreads. That is, the carbon price at which power generators will earn the same profit per unit of electricity regardless of whether they burn coal or gas.[65] Kanen (2006) contends that the fuel-switching price is the theoretical maximum price for carbon emissions, provided that all allowances are auctioned. Once the carbon price rises above the fuel-switching price, generators will switch from coal to gas (a cleaner burning fuel), thus increasing the supply of EUAs and causing the price to fall back toward the switching level.

[65] Kanen (2006) discusses the merit order of European power plants, and states that the EU price-setting power plant is always either a coal or gas plant. The merit order of power plants refers to the marginal power supply curve, which is based on the marginal cost of generating an additional MWh of electricity. Power sources with the lowest marginal cost (hydro, wind, nuclear) will be supplied first, followed by coal, gas, and then oil.

Table 2-4

Literature summary: Determinants of the EUA price

This table summarises studies that examine the determinants of the European Union Allowance (EUA) price and electricity price.

Study	Sample period	Data frequency	Dependent variable	Independent variable(s)	Direction of relationship	Statistical significance level
Kanen (2006)	1995 – 2005	Semi-Annual	Electricity spot price (p_t)	▪ Gas price (large user), Eurostat (p_t)*	n/a	Not Sig.
				▪ Coal price (large user), Eurostat (p_t)	n/a	Not Sig.
				▪ Spark spread (p_t)	(+)	5%
				▪ Dark spread (p_t)	(+)	5%
				▪ Brent Crude Oil price, Eurostat (p_t)	n/a	Not Sig.
Mansanet-Bataller, Tornero, and Mico (2006)	2005	Daily	EUA forward price (Δp_t)	▪ Brent Crude Oil futures, ICE (Δp_t)	(+)	10%
				▪ Brent Crude Oil futures, ICE (Δp_{t-1})	(+)	1%
				▪ Natural Gas futures, ICE (Δp_t)	(+)	Not Sig.
				▪ Natural Gas futures, ICE (Δp_{t-1})	(+)	Not Sig.
				▪ Electricity futures, EEX (Δp_t)	(+)	5%
				▪ Electricity futures, EEX (Δp_{t-1})	(+)	1%
				▪ Quotient between ΔGas_t and $\Delta Electricity_t$	(+)	1%
				▪ Extreme temperature	(+)	1%
				▪ Extreme rainfall	(+/-)	Not Sig.
Sijm, Neuhoff, and Chen (2006)	2004 - 2005	Daily	Electricity forward price (p_t)	▪ EUA forward price (p_t)	(+)	20%
Alberola and Chevallier (2007)	2005 – 2007	Daily	EUA spot price (Δp_t)	▪ Brent Crude Oil futures, ICE (Δp_t)	n/a	Not Sig.
				▪ Natural Gas spot (Δp_t)	(+)	5%
				▪ Natural Gas spot (Δp_{t-1})	(+)	5%
				▪ Temperature index	n/a	Not Sig.
				▪ French ban on banking	(+)	5%
				▪ Polish ban on banking	n/a	Not Sig.
				▪ Expected allowance scarcity	(+)	1%
Bunn and Fezzi (2007)	2005 – 2006	Daily	EUA spot price (Δp_t)	▪ UK day ahead electricity price (Δp_{t-1})	n/a	Not Sig.
				▪ UK day ahead gas price (Δp_{t-1})	(+)	5%
				▪ London temperature (Δp_t)	n/a	Not Sig.

Table 2-4 Continued

Study	Sample period	Data frequency	Dependent variable	Independent variable(s)	Direction of relationship	Statistical significance level
Daskalakis and Markellos (2007a)	2005 – 2007	Daily	Electricity spot and forward price *(Δp_t)*	▪ EUA spot price *(Δp_t)***	(+)	1%
Alberola, Chevallier, and Cheze (2008a)	2005 – 2007	Daily	EUA spot price *(Δp_t)*	▪ Brent Crude Oil futures, ICE *(Δp_t)*	n/a	Not Sig.
				▪ Brent Crude Oil futures, ICE *(Δp_{t-1})*	n/a	Not Sig.
				▪ Natural Gas futures *(Δp_t)*	(+)	1%
				▪ Coal futures *(Δp_t)*	(-)	5%
				▪ Electricity futures, Powernext *(Δp_t)*	(+)	1%
				▪ Clean dark spread *(Δp_t)*	(-)	1%
				▪ Clean spark spread *(Δp_t)*	(+)	5%
				▪ Switch price *(Δp_t)*	n/a	Not Sig.
				▪ Extreme temperature DVs	(+/-)	Not Sig.
				▪ Sectorial production (country)	(+/-)	1% - Not Sig.
Alberola, Chevallier, and Cheze (2008b)	2005 – 2007	Daily	EUA spot price *(Δp_t)*	▪ Natural Gas futures *(Δp_t)*	(+)	1%
				▪ Coal futures *(Δp_t)*	(-)	1%
				▪ Electricity futures, Powernext *(Δp_t)*	(+)	1%
				▪ Clean dark spread *(Δp_t)*	(-)	1%
				▪ Clean spark spread *(Δp_t)*	(+)	1%
				▪ Extreme temperature DV	(-)	1%
				▪ Combustion production index, EU	(-)	1%
				▪ Iron & steel production index, EU	(-)	1%
				▪ Paper and board production index, EU	(-)	1%
				▪ Coke ovens, refineries, metal ore, cement, glass, and ceramics production indices	n/a	Not Sig.

* Kanen (2006) also examines each of the EU 15 individually, finding specific determinants were more significant in some countries when compared with others.
** Daskalakis et al. (2007a) examine the determinants of the electricity risk premium, a component of the electricity futures/forward price.

Four studies documented in Table 2-4 examine the effect of natural gas prices, coal prices, and clean dark/spark spreads on the price of EUAs. The positive coefficient of the natural gas variable in all studies suggests that as the price of natural gas increases, power generators will switch their fuel from gas to coal, increasing the demand for (and hence price of) EUAs.[67] Consistent with the observed impact of natural gas prices, coal prices have a negative and statistically significant effect on the EUA price. That is, higher coal prices lead power generators to switch their fuel from coal to gas, decreasing the demand for EUAs.

Alberola, Chevallier, and Chèze (2008a, 2008b) document a negative (positive) coefficient for clean dark (spark) spreads, suggesting that an increase in the profit per unit of electricity for a coal-fired (gas-fired) plant leads to a lower (higher) EUA price. However, the inclusion of clean dark spreads and clean spark spreads as determinants of the EUA price is problematic. There is a natural correlation between clean dark spreads and the coal price, clean spark spreads and the gas price, and clean dark/spark spreads and the carbon price. Any model that incorporates these four variables, such as the models tested in Alberola et al. (2008a, 2008b), will violate two assumptions of the classical linear regression model.[68]

[67] The statistical strength of the relation between the carbon price and natural gas price varies across studies. Mansanet-Bataller, Tornero, and Mico (2006) report the natural gas variable is not statistically significant, Alberola and Chèze (2007) report statistical significance at the 0.05 level, and Alberola, Chevallier, and Chèze (2008a, 2008b) report statistical significance at the 0.01 level.

[68] Specifically, they violate the CLRM assumptions that there is no multicollinearity among the regressors and that independent variables are nonstochastic.

In Europe, the crude oil price affects the carbon price through its impact on the gas price. The relation between the prices of gas and oil is a result of the netback pricing mechanism employed in the European Union. Netback pricing links the natural gas price to the prices of fuel oil and gas oil (gas substitutes), which are in turn closely linked to crude oil prices. The European Union utilises this pricing mechanism to permit the recovery of large infrastructure investments (Kanen, 2006).

There is inconsistent evidence regarding the role of crude oil in determining the price of EUAs. Mansanet-Bataller, Tornero, and Mico (2006) report a positive and statistically significant coefficient for the crude oil price, providing evidence that an increase in the crude oil price leads to an increase in the EUA price. Conversely, Alberola and Chevallier (2007) and Alberola et al. (2008a) find that the price of crude oil is not a statistically significant determinant of the EUA price. These conflicting results could be a consequence of multicollinearity, as all three studies incorporate both the natural gas price and the crude oil price as independent variables.

The final important energy price, the electricity price, is most heavily influenced by the price of coal and gas (Kanen, 2006). Studies that incorporate the price of electricity as a determinant of the EUA price produce consistent results. Mansanet-Bataller et al. (2006) and Alberola et al. (2008a, 2008b) report a positive and statistically significant coefficient for electricity prices, demonstrating the importance of the electricity price in determining the EUA price.

Carbon pricing studies also test weather variables as determinants of the EUA price, primarily due to the known influence of extreme weather on electricity prices. Results across studies are inconclusive. Mansanet-Bataller et al. (2006) document a positive and statistically significant coefficient for extreme temperatures; however, extreme rainfall is insignificant. Conversely, Alberola et al. (2008b) find a negative and statistically significant coefficient for extreme temperatures, while Bunn and Fezzi (2007) and Alberola and Chevallier (2007) report that weather variables are not significant determinants of the EUA price. This inconsistency across studies could be a consequence of the correlation between the electricity price and extreme weather conditions.

Finally, Alberola et al. (2008a, 2008b) examine the influence of sectorial production indices on the EUA price. Alberola et al. (2008a) perform separate regressions for each Member State and find that within a country, production in different sectors influences the EUA price. For example, in Germany, production in the paper industry negatively affects the EUA price. Alberola et al. (2008b) improve on this methodology as they compute EU-wide indices, recognising that the carbon price depends on production across the entire European Union. They find that the combustion, iron and steel, and paper and board production indices negatively affect the EUA price, while other production indices are statistically insignificant.

Table 2-4 also reports studies that empirically test the carbon price as a determinant of the electricity price. Sijm, Neuhoff, and Chen (2006) and Daskalakis and Markellos (2007a) document a positive coefficient for EUA prices, providing evidence that the price of carbon dioxide emissions impacts on the electricity price.

Empirical studies of the determinants of the carbon emissions price face several problems, namely the correlations among energy prices and the feedback between dark/spark spreads and the carbon price. Thus far, no study has successfully disentangled the separate effects of natural gas, coal, crude oil, and electricity prices on the carbon price.

2.3.3 Information asymmetry and uncertainty

Panel A of Table 2-5 describes studies that examine information asymmetry and uncertainty in the European carbon market. The two central sources of information asymmetry and uncertainty in a carbon market include the setting of future emissions caps relative to future emissions (the supply constraint), and the verification of actual emissions.

Mansanet-Bataller and Pardo (2007) examine the impact of several information releases related to EU ETS emissions caps and verification of actual emissions. They document that returns are significantly higher on days when the European Commission released additional information on Phase I National Allocation Plans (NAPs), and on the day the European Commission approved Phase I NAPs. Mansanet-Bataller and Pardo (2007) also document significantly higher returns upon verification of 2005 emissions, and significantly lower returns upon verification of 2006 emissions. These results are significant at the 0.01 level, providing evidence that information regarding the supply of EUAs has a material effect on the carbon price.

Chevailler, Ielpo, and Mercier (2008) examine the impact of emissions verification by analysing the options market. They find that the implied volatility for December 2008 and December 2009 EUA options is lower after the European Commission announced 2006 emissions. Again, this provides evidence that EUA supply uncertainty affects the carbon market.

2.3.4 Market efficiency and price discovery

Several studies empirically examine carbon market efficiency and price discovery; however, they produce inconsistent results. These studies are documented in Panel B of Table 2-5.

Table 2-5

Literature summary: Information asymmetry, uncertainty, market efficiency, and price discovery in the carbon market

This table summarises carbon market studies that examine information asymmetry and uncertainty (Panel A) and market efficiency and price discovery (Panel B).

A: Information asymmetry and uncertainty studies	Sample period	Carbon market	Data frequency	Information type	Effect on carbon market
Mansanet-Bataller and Pardo (2007)	2004 – 2007	Forward and futures	Daily	▪ News related to NAPs	▪ Returns were significantly higher (1% level) on days when additional information on Phase I NAPs was released, and on the day the EC approved Phase I NAPs.
				▪ News related to verification of emissions	▪ Returns were significantly higher (1% level) upon EC verification of 2005 emissions, and significantly lower (again, 1% level) upon EC verification of 2006 emissions
Chevallier, Ielpo, and Mercier (2008)	2006 – 2007	Futures and options	Daily	▪ Yearly compliance events	▪ Implied volatility for December 08 and December 09 options is lower after the EC announced 2006 compliance results.

B: Market efficiency and price discovery studies	Sample period	Carbon market	Data frequency	Efficiency tested	Outcome
Daskalakis and Markellos (2007b)	2005 – 2006	Spot and futures	Daily	▪ Weak form efficiency	▪ Carbon spot and futures markets are not weak form efficient.
Daskalakis, Psychoyios, and Markellos (2007)	2005 – 2006	Spot and futures	Daily	▪ Cost-of-carry pricing	▪ Intra-phase EUA futures are well described by the cost-of-carry model (with a zero convenience yield). ▪ Inter-phase EUA futures are not well described by the cost-of-carry model, and require an equilibrium pricing approach.
Milunovich and Joyeux (2007)	2005 – 2006	Spot and futures	Daily	▪ Cost-of-carry pricing	▪ EUA futures are not well described by the cost-of-carry model.
				▪ Price discovery	▪ Spot and futures markets share information efficiently and jointly contribute to price discovery.
Uhrig-Homburg and Wagner (2007)	2005 – 2006	Spot and futures	Daily	▪ Cost-of-carry pricing	▪ Within Phase I, futures prices are well described by the cost-of-carry approach (after an initial period of inefficiency).
				▪ Price discovery	▪ Futures market leads price discovery process

A common theme among market efficiency studies is the applicability of cost-of-carry pricing to the carbon futures market. One difficulty in applying the cost-of-carry model to European carbon futures is the restriction on banking Phase I EUAs for use in Phase II. The banking restriction imposed by the European Commission resulted in Phase II futures trading without a spot market for almost two years. Daskalakis, Psychoyios, and Markellos (2007) overcome this problem by analysing intra-phase and inter-phase futures separately. They find that for intra-phase futures, the cost-of-carry model with a zero convenience yield adequately describes the relation between spot and futures prices. Conversely, for inter-phase futures, Daskalakis et al. (2007) develop an equilibrium pricing approach, as the cost-of-carry model is inappropriate. These results are supported by Uhrig-Homburg and Wagner (2007), who find that within Phase I, futures prices are well described by the cost-of-carry model. However, as the European Commission has since declared Phase II EUAs are fungible with Phase III EUAs, there is no longer a need to examine intra-phase and inter-phase futures separately.

In contrast to both Daskalakis et al. (2007) and Uhrig-Homburg and Wagner (2007), Milunovich and Joyeux (2007) test the cost-of-carry model and show that it does not adequately describe EUA futures prices. These inconsistent results could be attributed to methodological differences between the studies. Specifically, Milunovich and Joyeux (2007) apply the cost-of-carry model to inter-phase futures, while Daskalakis et al. (2007) provide evidence that the cost-of-carry model is only applicable to intra-phase futures. In addition, stale spot market prices could create measurement issues, even when daily prices are used in the analysis.

Daskalakis and Markellos (2007b) test another form of market efficiency – weak form efficiency. Specifically, they test whether technical trading rules are profitable in the carbon spot and futures markets. Daskalakis and Markellos (2007b) find that almost all of the employed technical trading rules are profitable, providing evidence against weak form efficiency in the European carbon market.

Both Uhrig-Homburg and Wagner (2007) and Milunovich and Joyeaux (2007) examine the price discovery process in the EU ETS. Uhrig-Homburg and Wagner (2007) examine the spot and futures markets, and find that the futures market leads the price discovery process. This result is supported by The World Bank's carbon trading statistics, which show that in 2007 the futures/forward market accounted for 95 per cent of EU ETS volume. Spot markets account only for 2 per cent of trading. Therefore, it is surprising that Milunovich and Joyeaux (2007) find the spot and futures markets jointly share the price discovery process. This seems unlikely, as trading in the spot EUA market is very thin.

2.4 Hypothesis development

This section uses the literature reviewed in the previous three sections to develop the hypotheses tested in this dissertation.

Equity market literature documents a permanent effect in block purchases and sales, suggesting large trades in equity markets are executed by informed traders and contain information. Conversely, block transactions in futures markets have a low probability of containing information. Informed trades in interest rate contracts require a central bank to leak interest rate information (Frino and Oetomo, 2005) and stock index contracts diversify away any stock-specific information (Subrahmanyam, 1991). The first hypothesis ($H_{3,1}$) predicts that block trades in futures markets do not contain information.

Hypothesis$_{3,1}$: *There is no significant permanent price effect associated with block purchases and block sales in futures markets.*

Restrictions on short selling in equity markets provide one explanation for the documented asymmetry in the permanent effect (Chan and Lakonishok, 1993). No such restrictions exist in futures markets, suggesting that block purchases and block sales should behave similarly. Berkman et al. (2005) report no asymmetry in the price behaviour surrounding trades in stock index futures and Frino and Oetomo (2005) find no post-trade asymmetry in stock index futures and interest rate futures. Thus, the following hypothesis ($H_{3,2}$) predicts there will be no asymmetry in the permanent price effect.

Hypothesis$_{3,2}$: *There is no asymmetry in the permanent price effect when comparing block purchases with block sales in futures markets.*

Analogous to the stealth trading hypothesis presented in Barclay and Warner (1993), Chan and Lakonishok (1995) argue that investors break up large orders into sequences of smaller trades to minimise their price impact. They contend it is misleading to examine price behaviour surrounding individual trades, and suggest the correct unit of analysis is the entire sequence of trades, i.e. the trade package. If institutional investors execute large orders through a series of smaller trades, their consecutive purchases (sales) generate upward (downward) price pressure in the market over a period of time. This price pressure will continue until the investor exits the market, preventing a reversal in price until the order is fully executed.

Frino and Oetomo (2005) aggregate individual trades that belong to the same institutional order and examine price behaviour surrounding an entire trade package. Analysing trade packages removes any upward bias in the permanent effect for individual trades, as it allows price pressure created by the package to dissipate prior to capturing the post-trade benchmark. Consistent with results in Frino and Oetomo (2005), the next hypothesis ($H_{4,1}$) predicts that trade packages in futures markets do not contain information.

Hypothesis$_{4,1}$: *Trade packages are not associated with a significant permanent price effect.*

However, when a single trade is part of a large order exerting price pressure in the market over a period of time, it can appear to have a permanent price effect if the benchmark price is intraday, regardless of whether the trade actually contains information.[71]

The above discussion leads to the following hypothesis ($H_{4,2}$).

Hypothesis$_{4,2}$: *Individual trades that belong to trade packages are associated with a significant permanent price effect.*

One implication of the rationale provided by Chan and Lakonishok (1995) is that any price reversal, which is likely to be associated with the execution of a package, will not occur until after the entire package is executed. Therefore, any bias in the permanent effect should be removed if trade package benchmarks are applied to each individual trade belonging to that package. This produces a measure of the permanent price effect unperturbed by the price pressure associated with the completion of an individual trade's respective trade package.

The above discussion leads to the following hypothesis ($H_{4,3}$).

[71] A permanent price effect is measured as the return from a pre-trade to post-trade benchmark. If a single "buy" trade is part of a larger institutional purchase order, the post-trade benchmark is biased upward due to price pressure exerted by the order. The converse applies to single "sell" trades. In either situation, the results are biased toward finding a permanent price effect.

Hypothesis$_{4,3}$: *After applying benchmarks from the trade package to each individual trade from that package, individual trades are not associated with a significant permanent price effect.*

In contrast with transparent equity and futures markets, empirical studies of opaque markets report that execution costs decline with trade size. This effect is documented in several opaque markets, including the US corporate and municipal bond markets and the London dealer market. The next hypothesis ($H_{5,1}$) predicts that due to its opaque structure, execution costs will also decline with trade size in the money market.

Hypothesis$_{5,1}$: *Execution costs decline with trade size in the money market.*

Literature offers two competing explanations for the documented negative relation between execution costs and trade size in opaque markets. First, the price information hypothesis proposes that institutions actively trading in non-transparent markets acquire an enhanced knowledge of market prices. The major proponents of this hypothesis, namely Schultz (2001) and Harris and Piwowar (2006), then suggest that active institutions will use their superior price information to minimise execution costs. Second, the relationship hypothesis proposes that the strength of the relationship between broker and dealer drives the negative relation between execution costs and trade size. That is, brokers will receive greater price improvements from dealers with whom they have an established relationship.

Both hypotheses assert that the negative relation between execution costs and trade size arises as large trades are disproportionately executed by institutions with superior price information or brokers with established dealer relationships.

The price information hypothesis ($H_{5,2}$) predicts that traders with *ex ante* price information will incur lower execution costs, while the relationship hypothesis ($H_{5,3}$) predicts that traders with strong broker-client relationships will incur lower execution costs.

Hypothesis$_{5,2}$: *A trader's ex ante price information is an important determinant of execution costs in an opaque market, and the direction of the relationship is negative. That is, traders with ex ante price information will incur lower execution costs.*

Hypothesis$_{5,3}$: *The strength of the relationship between broker and client is an important determinant of the client's execution costs in an opaque market, and the direction of the relationship is negative. That is, clients that establish strong broker-client relationships will incur lower execution costs.*

Schultz (2001) is the only study to test both $H_{5,2}$ and $H_{5,3}$. He finds that an institution's *ex ante* price information is a statistically significant determinant of execution costs while trading relationships are not. Therefore, the following hypothesis ($H_{5,4}$) predicts that the price information hypothesis is the dominant effect.

Hypothesis$_{5,4}$: *A trader will achieve a greater reduction in execution costs by obtaining ex ante price information than by establishing a strong relationship with their broker.*

The nine hypotheses presented thus far explore execution costs in developed markets. In contrast, the EU ETS is a relatively new market, established by the European Commission in 2005. Domowitz et al. (2001) examine panel data for equity markets in 42 countries and report that the primary factor influencing trading activity is market development. Similar to the findings in Domowitz et al. (2001), the next hypothesis ($H_{6,1}$) predicts that trading activity will increase as the carbon futures market develops.

Hypothesis$_{6,1}$: *Trading activity in the carbon futures market will improve as the market matures.*

Domowitz et al. (2001) also document a substantial reduction in trading costs from September 1996 to December 1998 for emerging markets. Consistent with Domowitz et al. (2001) and the notion that lower costs of trading are associated with improved liquidity, the next hypothesis ($H_{6,2}$) predicts that trading costs in the carbon futures market decrease considerably over time.

Hypothesis$_{6,2}$: *In line with the improvement in trading activity, the bid-ask spread will decline and market depth will increase in the carbon futures market.*

New and emerging markets are also characterised by high levels of price volatility (Domowitz et al., 2001). In the European carbon market, this natural price volatility was exacerbated by the supply uncertainty surrounding Phase I EUAs, which also cast doubt on the strength of Phase II caps. This is discussed in detail in Chapter 6. Subsequently, the following hypothesis ($H_{6,3}$) predicts that there is a high level of price volatility in the carbon futures market.

Hypothesis$_{6,3}$: *There is substantial volatility in carbon futures prices; however, volatility will decline as the market matures.*

Carbon futures have a higher probability of containing information than trades in stock index and interest rate futures. Private information regarding actual emissions is known at the firm and Member State level well in advance of the European Commission's official release date in early May each year.[72] Additionally, approximately 60 per cent of daily carbon futures trading occurs off-market via the ICE Futures Exchange for Physical (EFP) facility – primarily used by liquidity traders (i.e. hedgers and arbitrageurs). The

[72] At the firm level a select group of employees and auditors have advanced knowledge of a firm's net position in EUAs. At the Member State level, government employees have advance knowledge of each firm's net position in EUAs.

prominence of liquidity trading via the EFP facility implies a greater concentration of informed trading in the limit order book. The above discussion leads to the final hypothesis ($H_{6,4}$).

Hypothesis$_{6,4}$: *In contrast to traditional futures contracts, on-market block trades in carbon futures markets are likely to contain information.*

2.5 Summary

This chapter reviews literature concerned with the price impact of trades in futures and opaque markets, and literature that empirically examines the European carbon market. This chapter also develops several hypotheses that are tested in the following chapters. Chapter 3 examines price impact and its components across 14 stock index futures contracts traded on 11 international markets. Chapter 4 examines price behaviour surrounding individual trades and trade packages in futures markets. Chapter 5 examines the determinants of execution costs in the money market. The final chapter, Chapter 6, examines liquidity and transaction costs in the European carbon futures market.

Chapter 3

Price behaviour surrounding block transactions in stock index futures markets: International evidence

3.1 Introduction

Futures markets provide a transparent mechanism for institutional risk transfer and price discovery. Despite their importance to global financial markets, few studies examine the price behaviour surrounding block transactions in futures markets. The literature review in Section 2.1.2 highlights only one futures market study, Berkman et al. (2005), which examines the price impact of large individual trades. Chapter 3 fills this void in the literature by examining the price behaviour surrounding 14 stock index futures contracts trading on 11 different markets.

Prior literature suggests that transactions in futures markets have a low probability of containing information. The first hypothesis ($H_{3,1}$) predicts that block trades in futures markets are not associated with a permanent price effect. Prior literature also suggests that block buys and block sells in futures markets should behave symmetrically, as there are no short selling restrictions in futures markets. Therefore, the second hypothesis ($H_{3,2}$) predicts that there is no asymmetry in the permanent price effect when comparing block purchases with block sales in futures markets.

The remainder of this chapter is organised as follows. Section 3.2 describes the data and sample, and provides institutional details. Section 3.3 documents the research design. Section 3.4 presents the results, while Section 3.5 presents results from additional tests. A summary of the chapter is in Section 3.6.

3.2 Data, sample, and institutional detail

3.2.1 Data and sample

The data used in this chapter are sourced from Reuters and describe transactions executed in 14 stock index futures from January 1, 2001 to December 31, 2005. The sample includes trades from the DAX, FTSE100, CAC40, OMXS30, S&P500 GLOBEX, Hang Seng Index, KOSPI 200, MSCI Singapore, MSCI Taiwan, SPI 200, TOPIX, Nikkei 225 (OSE), Nikkei 225 (SGX) and TAIEX stock index futures contracts. Each trade record contains fields which document the date, time, price, volume, best bid and best ask associated with each trade. Bid and ask quotes are the prevailing best quotes immediately prior to the trade.

Block trades are defined as the largest two per cent of trades, by volume, for each contract. Trades are classified as buyer- or seller-initiated using the classification algorithm from Ellis, Michaely, and O'Hara (2000).[75] In this algorithm, trades are initially classified using a quote-based rule. Trades executed at the best ask quote are classified as buyer-initiated and trades occurring at the best bid quote are classified as seller-initiated. Any trades not

[75] This classification algorithm is similar to the algorithm of Lee and Ready (1991).

captured by this classification rule are classified using a tick rule, where trades occurring on an up-tick are classified as buyer-initiated and trades occurring on a down-tick are classified as seller-initiated. Any remaining unclassified trades are excluded from the sample.[76]

The sample is restricted to electronic trading in the near contract during daytime trading hours.[77] Trades occurring on the expiration day of the near contract are excluded.[78] Some exchanges have a facility for executing large block trades off-market. Transactions that meet off-market size requirements are excluded from the sample as off-market trades arrive to the market crossed and in some instances reporting is delayed.[79]

Table 3-1 presents descriptive statistics for block trades in the 14 stock index futures contracts examined in this chapter. Panel A reports statistics for buys and Panel B reports statistics for sells. There are significant differences in sample sizes across contracts. The DAX, FTSE100, CAC40, and KOSPI 200 have sample sizes greater than 100,000 for block buys and sells; the Hang Seng, SPI 200, TOPIX, Nikkei 225 (OSE), and TAIEX have sample sizes for buys and sells between 20,000 and 100,000; and the OMXS30, S&P500

[76] Over 99 per cent of trades in the sample are classified using this algorithm.
[77] The exception for this is S&P500 stock index futures. This contract is traded on the floor during daytime hours, and traded electronically through Globex® overnight.
[78] Frino and McKenzie (2002) report abnormal price behaviour in the period prior to contract expiration. Therefore, trades on the contract expiration day are removed from the sample to alleviate potential bias as traders roll their positions from the near to deferred contract.
[79] Berkman et al. (2005) also exclude off-market trades from their analysis.

GLOBEX, MSCI Singapore, MSCI Taiwan and Nikkei 225 (SGX) have sample sizes less than 20,000 for both block buys and sells.

Panels A and B of Table 3-1 describe the size of transactions in terms of contract volume and notional trade value in US dollars.[80] The sample has a large range in mean trade volume. OMXS30 futures have the greatest average volume of 1,164.01 contracts and MSCI Singapore futures have the lowest average volume of 9.67 contracts. The mean notional trade value also has a large range, with values ranging from USD 0.46 million for MSCI Singapore futures up to USD 9.256 million for OMXS30 futures.[81] Overall, buyer- and seller-initiated transactions across all markets are relatively similar.

3.2.2 Institutional detail

Table 3-2 reports contract specifications, contract size, and some aspects of market design for each stock index futures contract examined in this chapter.

[80] Notional trade value is calculated as [*price*volume*index multiplier*fx rate*] where *price* is the trade price, *volume* is the number of contracts, *index multiplier* is the dollar value per index point as reported in Table 3-2 and *fx rate* is the daily USD exchange rate provided by the US Federal Reserve.

[81] OMXS30 futures do not have an off-market block trading facility. This explains the large mean and variance for trades in this contract.

Table 3-1

Descriptive statistics for block trades: Volume traded and notional trade value

This table reports descriptive statistics for block trades in the 14 stock index futures contracts examined in this chapter. Block trades represent the largest two per cent of trades in each contract after removing trades that meet the minimum volume threshold for off-market block transactions. Panel A reports statistics for buys and Panel B reports statistics for sells. The mean, median and standard deviation is reported for volume traded and notional trade value. Volume traded is the average number of contracts per trade. Notional trade value is calculated as [*price*volume*index multiplier*fx rate*] where *price* is the trade price, *volume* is the number of contracts, *index multiplier* is the dollar value per index point as reported in Table 3-2 and *fx rate* is the daily exchange rate to USD as provided by the US Federal Reserve. Notional value is reported in thousands of US Dollars (USD '000s).

Panel A: Buys

	Volume traded (no. contracts)			Notional trade value (USD '000s)			
Contract	*Mean*	*Median*	*Std dev.*	*Mean*	*Median*	*Std dev.*	*N*
DAX	74.34	47.00	58.60	7,119.90	4,494.31	6,539.64	235,064
FTSE100	71.46	40.00	103.41	3,828.30	2,223.31	6,605.42	250,916
CAC40	64.65	49.00	46.55	1,685.65	1,387.08	1,734.09	204,489
OMXS30	1,085.08	387.00	2,688.06	8760.04	2,737.53	20,541.07	2,411
S&P500 GLOBEX	30.41	19.00	197.75	6,445.94	4,076.06	46,062.40	17,540
Hang Seng	34.88	30.00	15.99	1,890.79	1,910.28	1,479.17	91,294
KOSPI 200	271.80	230.00	125.96	8,936.76	8,533.71	6,407.01	208,755
MSCI Singapore	9.67	8.00	6.01	194.74	174.91	174.15	15,304
MSCI Taiwan	26.39	21.00	12.87	467.09	486.18	365.82	8,283
SPI200	33.96	28.00	18.36	1,164.81	1,017.84	1,202.62	25,038
TOPIX	59.77	52.00	13.72	5,660.69	5,513.28	2,082.38	23,997
Nikkei 225 (OSE)	79.56	79.00	10.74	7,009.30	7,064.30	2,043.25	25,428
Nikkei 225 (SGX)	73.10	60.00	33.54	2,374.35	2,587.73	2,129.04	5,021
TAIEX	34.88	30.00	15.99	1,890.79	1,910.21	1,479.16	91,294

Table 3-1 Continued

Panel B: Sells	Volume traded (no. contracts)			Notional trade value (USD '000s)			
Contract	*Mean*	*Median*	*Std dev.*	*Mean*	*Median*	*Std dev.*	*N*
DAX	69.34	40.00	59.63	7,237.10	4,530.18	6,725.30	142,070
FTSE100	69.04	40.00	100.49	4,088.29	2,478.74	6,739.70	156,892
CAC40	62.29	48.00	43.63	1,851.93	1,581.27	1,661.57	141,443
OMXS30	1,164.01	400.00	2,698.81	9,256.18	2,966.26	21,567.18	2,506
S&P500 GLOBEX	40.07	19.00	704.21	8,929.75	4,045.65	198,098.59	18,101
Hang Seng	34.78	30.00	16.07	1,863.99	1,889.14	1,473.52	92,634
KOSPI 200	271.19	230.00	156.85	8,880.50	8,484.03	7,044.86	216,453
MSCI Singapore	9.68	8.00	6.59	46.51	168.34	179.18	14,969
MSCI Taiwan	26.63	21.00	13.61	466.02	479.38	383.21	7,976
SPI200	34.06	28.00	18.89	1,179.46	1,017.35	1,266.28	24,548
TOPIX	59.75	51.00	13.84	5,659.67	5,511.35	2,110.19	23,024
Nikkei 225 (OSE)	79.46	79.00	10.69	6,952.28	7,004.48	2,025.27	25,765
Nikkei 225 (SGX)	72.28	60.00	32.96	2,325.92	2,584.08	2,038.73	4,865
TAIEX	34.78	30.00	16.07	1,863.99	1,889.14	1,473.52	92,634

3.3 Research design

The pre- and post-trade benchmarks employed in this chapter to measure price impact are the transaction prices five trades before and five trades after the block trade, respectively; analogous to the benchmarks used in Berkman et al. (2005). The calculation of total, temporary and permanent price effects is consistent with Chan and Lakonishok (1993) and permits testing of hypotheses $H_{3,1}$ and $H_{3,2}$. *Total* measures the total price impact of a trade, and can be decomposed into *Temporary* (liquidity) and *Permanent* (information) effects, as follows –

$$Total_{i,t} = \left[\frac{Price_t - Price_{t-5}}{Price_{t-5}}\right]*100 \tag{3-1}$$

$$Temporary_{i,t} = \left[\frac{Price_{t+5} - Price_t}{Price_t}\right]*100 \tag{3-2}$$

$$Permanent_{i,t} = \left[\frac{Price_{t+5} - Price_{t-5}}{Price_{t-5}}\right]*100 \tag{3-3}$$

For each trade, $Price_t$ is the transaction price, $Price_{t-5}$ is the price five trades preceding the trade, and $Price_{t+5}$ is the price five trades after the trade.[82]

[82] The large samples examined in this chapter necessitate adjustment of the *t*-value critical level to alleviate Lindley's paradox. The new critical value t^* is calculated using the following formula:

$$t^* = \sqrt{[c^{\frac{2}{T}} T^{\frac{1}{T}} - 1](T - k)}$$

where c is the ratio between the Bayesian probabilities of the null and alternative hypotheses; T is the sample size and k is the number of regressors in the model. Derivation and further explanation of this adjustment is found in Johnstone (2005).

Table 3-2
Contract specifications, contract size and market design

This table reports contract specifications and market design details for each of the 14 stock index futures contracts examined in this chapter. *Exchange* is the main exchange on which the contract is traded, *minimum tick* is the minimum price increment, *notional value per index point* is the dollar value (in local denominations) of each index point, *relative minimum tick* is the minimum price increment divided by the average index level at 30/12/2005, *notional value of one contract* is the dollar value of each index point multiplied by the index level at 30/12/2005 and converted to US dollars using the exchange rate provided by the US Federal Reserve on that day, *off-market threshold* is the minimum number of contracts per trade required for off-market trading , *overnight trading* indicates an overnight trading session, *cash/futures open first* indicates if the cash or futures market opens first (based on regular trading hours), and *cash/futures close first* indicates if the cash or futures market closes first (based on regular trading hours).

	Contract Specifications			Contract Size		Market Design			
Contract	*Exchange*	*Minimum tick*	*Notional value per index point*	*Relative Minimum tick*	*Notional value of one contract (USD)*	*Off-market threshold*	*Overnight trading*	*Cash/ futures open first*	*Cash/ futures close first*
DAX	Eurex	0.5 points	EUR 25	0.000091	161,942.52	250	No	Futures	Cash
FTSE100	Euronext.liffe	0.5 points	GBP 10	0.000089	96,580.42	750	No	Same	Cash
CAC40	Euronext.liffe	0.5 points	EUR 10	0.000106	55,856.61	N/A	No	Futures	Cash
Hang Seng	HKE	1 point	HKD 50	0.000067	95,936.12	100	No	Futures	Cash
KOSPI 200	KSE	0.05 points	KRW 500,000	0.000036	683,533.20	N/A	No	Same	Cash
MSCI Singapore	SGX	0.1 points	SGD 200	0.000359	33,498.92	200	No	Futures	Cash
MSCI Taiwan	SGX	0.1 points	USD 100	0.000362	27,581.00	200	Yes	Futures	Cash
Nikkei 225	OSE	10 points	JPY 1,000	0.000621	136,676.53	100	No	Same	Cash
Nikkei 225	SGX	5 points	JPY 500	0.000312	68,338.27	300	Yes	Futures	Cash
OMXS30	OMX	0.25 points	SEK 100	0.000260	12,095.38	N/A	No	Same	Same
S&P500 GLOBEX	CME	0.1 points	USD 250	0.000080	312,072.50	N/A	Yes	N/A*	N/A*
SPI200	SFE	1 point	AUD 25	0.000209	87, 432.20	300	Yes	Futures	Cash
TOPIX	TSE	0.5 points	JPY 10,000	0.000303	139,952.49	100	No	Same	Cash
TAIEX	TFE	1 point	TWD 200	0.000153	39,928.90	N/A	No	Futures	Cash

* The data used in this chapter are for the overnight trading session. The cash market is not open during this session.

3.4 Empirical results

Table 3-3 reports estimates of total, temporary and permanent price effects for block buys and block sells. The total price effect for all contracts is positive and statistically significant for block buys and negative and statistically significant for block sells. The direction and statistical significance of the total price effect is consistent with prior equities and futures markets research; however, the magnitude is smaller than previously reported, with all estimates less than (or equal to) 2.5 basis points. The total price effect reported for the largest trade size category in Berkman et al. (2005) is less than six basis points, compared with the maximum 2.5 basis points reported for S&P500 GLOBEX futures in Table 3-3.[83]

Results for the temporary effect are reported in Table 3-3. For block buys, the temporary price effect is negative in 11 of the 14 contracts examined, and statistically significant in nine. This implies buyers incur a liquidity premium to transact large blocks in the majority of the contracts examined in this chapter. Results for block sells are analogous to block buys, with the majority of contracts incurring a statistically significant positive temporary price effect. On balance, this analysis provides strong evidence that traders pay a liquidity premium to transact large block trades in futures markets, consistent with results for the largest trade size category in Berkman et al. (2005).

[83] Sample differences are one potential cause of this variation in the magnitude of price impact. This Chapter examines data covering five years from 2001 to 2005, while Berkman et al. (2005) examine three months in 2000. Average daily turnover in futures markets has increased dramatically since the Berkman et al. (2005) sample period, and this enhanced liquidity could contribute to a fall in the magnitude of the total price effect over time.

Results for the permanent effect are reported in Table 3-3. All contracts have a positive permanent price effect for block buys, which is statistically significant in 10 of the 14 contracts examined. This suggests that block buys in these 10 contracts are executed by informed traders. For block sells, the permanent price effect is negative in 13 of the 14 contracts examined, and statistically significant in 12 of the contracts. The results documented in Table 3-3 provide overwhelming evidence that large trades in futures markets contain information, clearly rejecting hypothesis $H_{3,1}$. Berkman et al. (2005) report a complete price reversal for both buys and sells in their largest trade size category, finding no evidence of a significant permanent price effect for large trades. In Table 3-3, only FTSE100 and Nikkei 225 (OSE) futures have a complete price reversal for buys and sells, suggesting the findings in Berkman et al. (2005) cannot be generalised to incorporate all futures contracts.

Table 3-3
Total, temporary and permanent price effects for block trades: Five-trade benchmarks

This table reports returns surrounding block trades for each of the 14 contracts examined in this chapter. Block trades represent the largest two per cent of trades in each contract after removing trades that meet the minimum threshold for off-market block transactions. *Total* is the percentage return from the price five trades prior to the trade to the trade price. *Temporary* is the percentage return from the trade price to price five trades after the trade. *Permanent* is the percentage return from the price five trades prior to the trade to the price five trades after the trade. *Abs(buys) – Abs(sells)* is the mean difference in the permanent price effect for buys and sells. A *t*-test is used to test the deviation of mean values from zero and critical t-values are adjusted for sample size.

	Total		Temporary		Permanent		
Contract	*Buys*	*Sells*	*Buys*	*Sells*	*Buys*	*Sells*	*Abs(buys) - Abs(sells)*
DAX	0.0045**	-0.0063**	-0.0043**	0.0047**	0.0002	-0.0016**	-0.0014**
FTSE100	0.0084**	-0.0028**	-0.0067**	0.0040**	0.0017	0.0012	0.0005
CAC40	0.0075**	-0.0068**	-0.0037**	0.0024**	0.0038**	-0.0044**	-0.0006
OMXS30	0.0177**	-0.0176**	-0.0073**	0.0087**	0.0104**	-0.0089**	0.0015
S&P500 GLOBEX	0.0227**	-0.0250**	-0.0008	0.0007	0.0219**	-0.0245**	-0.0026
Hang Seng	0.0117**	-0.0123**	-0.0060**	0.0058**	0.0057**	-0.0065**	-0.0008
KOSPI 200	0.0107**	-0.0112**	-0.0106**	0.0101**	0.0001	-0.0011**	-0.0010**
MSCI Singapore	0.0206**	-0.0197**	0.0045**	-0.0030**	0.0251**	-0.0227**	0.0024
MSCI Taiwan	0.0155**	-0.0153**	0.0007	-0.0007	0.0162**	-0.0160**	0.0002
SPI200	0.0158**	-0.0155**	0.0032**	-0.0033**	0.0190**	-0.0188**	0.0002
TOPIX	0.0103**	-0.0091**	-0.0060**	0.0056**	0.0043**	-0.0035**	0.0008
Nikkei 225 (OSE)	0.0209**	-0.0200**	-0.0186**	0.0177**	0.0023	-0.0023	0.0000
Nikkei 225 (SGX)	0.0122**	-0.0111**	-0.0005	0.0009	0.0117**	-0.0102**	0.0015
TAIEX	0.0117**	-0.0123**	-0.0060**	0.0058**	0.0057**	-0.0065**	-0.0008

* Significantly different from zero at the 5% level ** Significantly different from zero at the 1 % level

Berkman et al. (2005) also hypothesise that buy and sell trades in futures markets will behave symmetrically post-execution. Their analysis provides evidence to support this hypothesis, as they find no significant difference between permanent price effects for buy and sell trades. For each contract examined in this chapter, Table 3-3 reports the mean difference between buys and sells for the permanent price effect. Consistent with the prediction of hypothesis $H_{3,2}$, the majority of contracts in Table 3-3 have symmetrical permanent price effects for buys and sells. There is no significant difference in the mean permanent price effect for 12 of the 14 futures contracts examined.[84]

The results presented in Table 3-3 provide evidence that price behaviour surrounding block trades differs across contracts and markets. There are numerous market and contract design issues potentially contributing to this inconsistency. Some examples of potential differences include contract size (Karagozoglu and Martell, 1999), the availability of off-market trading facilities (Madhavan and Cheng, 1997), and the transfer of information between futures and cash markets (Fleming, Ostdiek, and Whaley, 1996). Section 3.2.2 contains a table describing contract specifications, contract size and some aspects of market design for each contract examined in this study.[85]

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[84] Block sells in DAX and KOSPI200 futures have a permanent price effect significantly larger in magnitude than block buys.

[85] This table is by no means exhaustive; there are many more market and contract design characteristics relevant to these contracts.

3.4 Additional tests

This section discusses various robustness tests employed to confirm results presented in Section 3.3 by repeating the analysis using alternative pre- and post-trade benchmarks and an alternative definition of execution costs.

Chan and Lakonishok (1993, 1995) recognise the importance of benchmark selection in price impact studies. The first additional test examines the choice of benchmark by replacing the five-trade benchmark used in Eq. (3-1) to Eq. (3-3) with 10-trade benchmarks, with results reported in Table 3-4. The results presented in Table 3-4 are consistent with results in Table 3-3, providing evidence that changing the pre- and post-trade benchmark does not significantly affect results. Results are thus robust to the choice of pre- and post-trade benchmarks.

Table 3-4
Total, temporary and permanent price effects for block trades: 10-trade benchmarks

This table reports returns surrounding block trades for each of the 14 contracts examined in this chapter. Block trades represent the largest two per cent of trades in each contract after removing trades that meet the minimum threshold for off-market block transactions. *Total* is the percentage return from the mid-quote 10 trades prior to the trade to the trade price. *Temporary* is the percentage return from the trade price to mid-quote 10 trades after the trade. *Permanent* is the percentage return from the mid-quote 10 trades prior to the trade to the mid-quote 10 trades after the trade. *Abs(buys) – Abs(sells)* is the mean difference in the permanent price effect for buys and sells. A *t*-test is used to test the deviation of mean values from zero and critical t-values are adjusted for sample size.

	Total		Temporary		Permanent		
Contract	*Buys*	*Sells*	*Buys*	*Sells*	*Buys*	*Sells*	*Abs(buys) - Abs(sells)*
DAX	0.0050**	-0.0079**	-0.0041**	0.0048**	0.0009	-0.0031**	-0.0022**
FTSE100	0.0073**	-0.0016**	-0.0048**	0.0038**	0.0025	0.0022	0.0003
CAC40	0.0082**	-0.0076**	-0.0028**	0.0013**	0.0054**	-0.0063**	-0.0009
OMXS30	0.0189**	-0.0190**	-0.0129**	0.0102**	0.0060**	-0.0088**	-0.0028
S&P500 GLOBEX	0.0268**	-0.0310**	-0.0009	0.0002	0.0259**	-0.0308**	-0.0049
Hang Seng	0.0138**	-0.0142**	-0.0049**	0.0050**	0.0089**	-0.0092**	-0.0003
KOSPI 200	0.0123**	-0.0130**	-0.0112**	0.0094**	0.0011	-0.0036**	-0.0015*
MSCI Singapore	0.0248**	-0.0218**	0.0062**	-0.0035**	0.0310**	-0.0253**	0.0057
MSCI Taiwan	0.0185**	-0.0168**	0.0021	-0.0016	0.0206**	-0.0184**	0.0022
SPI200	0.0187**	-0.0182**	0.0048**	-0.0051**	0.0235**	-0.0233**	0.0002
TOPIX	0.0121**	-0.0094**	-0.0044**	0.0049**	0.0077**	-0.0045**	0.0032
Nikkei 225 (OSE)	0.0225**	-0.0219**	-0.0182**	0.0183**	0.0043	-0.0036	0.0007
Nikkei 225 (SGX)	0.0147**	-0.0145**	-0.0018	0.0003	0.0129**	-0.0142**	-0.0013
TAIEX	0.0138**	-0.0142**	-0.0049**	0.0050**	0.0089**	-0.0092**	-0.0003

* Significantly different from zero at the 5% level ** Significantly different from zero at the 1 % level

The calculations of total, temporary and permanent price effects in Berkman et al (2005) are different to those used in this chapter. The second test ensures results are consistent with Berkman et al. (2005) and provides a further test of the technique employed to measure total, temporary and permanent price effects in block trades. In addition to a test of measurement techniques, the second test also investigates whether price movements reported in Section 3.3 capture bid-ask bounce as the test uses contemporaneous quote midpoints instead of transaction prices. Koski and Michaely (2000) recognise a potential bid-ask bias when measuring price impact using transaction prices and overcome this problem by calculating price impact using quoted returns. [86]

In the Berkman et al. (2005) analysis, effective half spreads, realised spreads and permanent price effects are synonymous with total, temporary and permanent price effects respectively. These alternative measures of price impact and its components are taken from Berkman et al. (2005) and are calculated as

$$Effective\ half\ spread = 100 D_i \ln(Price_i / MQBefore_i) \quad (3\text{-}4)$$

$$Realised\ half\ spread = 100 D_i \ln(Price_i / MQAfter_i) \quad (3\text{-}5)$$

$$Permanent\ price\ impact = 100 D_i \ln(MQAfter_i / MQBefore_i) \quad (3\text{-}6)$$

[86] Numerous studies recognise a potential bid-ask bias when using returns calculated with transaction prices, including Vijh (1988), Foerster, Keim, and Porter (1990), Lease, Masulis, and Page (1991), Bhardwaj and Brooks (1992), Gosnell, Keown, and Pinkerton (1996), Rhee and Wang (1997) and Frino, Jarnecic, Johnstone, and Lepone (2005).

where D_i is a binary variable that equals 1 for buys and -1 for sells, $Price_i$ is the value-weighted average price of the trade, $MQBefore_i$ is the mid-quote five trades before the block trade, and $MQAfter_i$ is the mid-quote five trades after the block trade.

Table 3-5 reports the results from this additional test. The results are consistent with Table 3-3 and Table 3-4, and show that the majority of contracts incur price impact which is permanent, indicating significant information content.

Table 3-5
Effective spreads, realised spreads, and permanent effects for block trades

This table reports returns surrounding block trades for each of the 14 contracts examined in this chapter. Block trades represent the largest two per cent of trades in each contract after removing trades that meet the minimum threshold for off-market block transactions. *Effective* is the effective half-spread and is measured as [$100*D_i*\ln(Price_i/MQBefore_i)$], where D_i is a binary variable that is 1 for buys and -1 for sells, $Price_i$ is the transaction price, and $MQBefore_i$ is the mid-quote five trades before trade *i*. *Realised* is the realised half-spread and is measured as [$100*D_i*\ln(Price_i/MQAfter_i)$], where D_i is a binary variable that is 1 for buys and -1 for sells, $Price_i$ is the transaction price, and $MQAfter_i$ is the mid-quote five trades after trade *i*. *Permanent* is the permanent effect and is measured as [$100*D_i*\ln(MQAfter_i/MQBefore_i)$], where D_i , $MQAfter_i$ and $MQBefore_i$ are defined as above. *Abs(buys) – Abs(sells)* is the mean difference in the permanent effect for buys and sells. A *t*-test is used to test the deviation of mean values from zero and critical t-values are adjusted for sample size.

	Effective		Realised		Permanent		
Contract	*Buys*	*Sells*	*Buys*	*Sells*	*Buys*	*Sells*	*Abs(buys) - Abs(sells)*
DAX	0.0046**	0.0065**	0.0044**	0.0051**	0.0002	0.0014**	-0.0012**
FTSE100	0.0043**	0.0032**	0.0066**	0.0054**	-0.0023	-0.0022	0.0001
CAC40	0.0076**	0.0081**	0.0038**	0.0037**	0.0038**	0.0044**	-0.0006
OMXS30	0.0189**	0.0184**	0.0087**	0.0102**	0.0102**	0.0082**	0.0020
S&P500 GLOBEX	0.0239**	0.0271**	0.0018	0.0023	0.0221**	0.0248**	-0.0027
Hang Seng	0.0127**	0.0135**	0.0071**	0.0069**	0.0056**	0.0066**	-0.0010
KOSPI 200	0.0131**	0.0141**	0.0162**	0.0123**	-0.0031	0.0018**	0.0013*
MSCI Singapore	0.0229**	0.0222**	-0.0009	0.0000	0.0238**	0.0222**	0.0016
MSCI Taiwan	0.0169**	0.0166**	-0.0013	-0.0023	0.0182**	0.0189**	-0.0007
SPI200	0.0166**	0.0168**	-0.0010**	-0.0012**	0.0176**	0.0180**	-0.0004
TOPIX	0.0104**	0.0098**	0.0063**	0.0062**	0.0041**	0.0036**	0.0005
Nikkei 225 (OSE)	0.0218**	0.0222**	0.0275**	0.0270**	-0.0057	-0.0048	0.0009
Nikkei 225 (SGX)	0.0149**	0.0142**	0.0046	0.0050	0.0103**	0.0092**	0.0011
TAIEX	0.0127**	0.0135**	0.0071**	0.0069**	0.0056**	0.0066**	-0.0010

* Significantly different from zero at the 5% level ** Significantly different from zero at the 1 % level

3.5 Summary

Only one prior study, Berkman et al. (2005), empirically examines the price impact of block trades in futures markets. The dearth of futures microstructure literature examining this topic is surprising, given that (i) there are numerous studies of price impact in equity markets, (ii) futures markets attract a large amount of liquidity, and (iii) futures markets provide a venue for risk transfer and price discovery. Chapter 3 of this dissertation contributes to the futures market microstructure literature by examining the price behaviour surrounding 14 stock index futures contracts trading on 11 different markets.

The results presented in Chapter 3 show that on balance, the initial price effect of futures block trades is partially reversed. That is, block trades incur a liquidity premium. The chapter also provides evidence that large buyer- and seller-initiated trades have a permanent effect on prices, implying they convey information. It is possible to conclude, similar to research based on equities markets, that traders in futures markets are informed.

Chapter 4

Transactions in futures markets: Informed or uninformed?

4.1 Introduction

The literature review in Section 2.1.2 highlights an inconsistency in futures microstructure literature. Berkman et al. (2005) and Kurov (2005) examine single trades in futures markets and find that overall they are associated with a permanent price effect, while Frino and Oetomo (2005) examine trade packages in futures markets and find they are not associated with a permanent price effect. In addition to the unit of analysis (individual trades versus packages) there are numerous other sample and methodological differences that could contribute to these inconsistent results. Chapter 4 adds to the literature in this area by attempting to resolve this inconsistency and determine whether transactions in futures markets contain information.

Chapter 3 documents a statistically significant permanent price effect for single block buy (sell) trades in 10 (12) different futures contracts, implying that individual trades in futures markets are executed by informed traders and contain information. However, if those individual trades are part of larger trade packages, the price pressure created by the execution of the package will generate a post-trade price movement similar to that associated with a permanent price effect. This post-trade price movement will occur for trades that belong to packages irrespective of their information content. Therefore, hypothesis $H_{4,2}$ predicts that individual trades that belong to trade packages are associated with a permanent price effect.

Frino and Oetomo (2005) argue, consistent with Chan and Lakonishok (1995), that it is necessary to examine the price impact of the entire trade package if investors split their order into a sequence of smaller trades. When analysing trade packages in futures markets, Frino and Oetomo (2005) find no evidence of a permanent effect; trade packages only incur liquidity costs. They also postulate that transactions in futures markets have a low probability of containing information. Therefore, hypothesis $H_{4,1}$ predicts that when individual trades are combined to form trade packages there is no permanent effect associated with the package.

The execution of a trade package over time creates price pressure in the market, and this price pressure will persist until the entire trade package is executed. Thus, the final hypothesis ($H_{4,3}$) predicts that after applying benchmarks from the trade package to each individual trade from that package, individual trades are not associated with a permanent price effect.

The remainder of this chapter is organised as follows. Section 4.2 describes the data and subsequent sample, and provides institutional details. Section 4.3 documents the research design. Sections 4.4 and 4.5 present the empirical results, while Section 4.6 presents results from additional tests. The chapter is summarised in Section 4.7.

4.2 Data, sample, and institutional detail

4.2.1 Data and sample

Chapter 4 utilises a proprietary data set from the Sydney Futures Exchange (SFE) describing all transactions from January 1, 2001 to December 31, 2005 in the four major contracts traded on the exchange. These contracts are 90-day bank accepted bill futures (BABs), 3-year bond futures, 10-year bond futures, and SPI 200 index futures. The data contain date, time (to the nearest second), price, trade direction, and volume fields, as well as an alphanumeric account code that identifies the investor behind each trade. The sample is restricted to trades in the near and deferred contracts during daytime trading hours. Trades occurring within 10 days of expiration of the near contract are excluded from the analysis, as these trades are likely to form part of rollover strategies (Frino and McKenzie, 2002).[87] Also excluded are trades by locals, trade packages greater than 10,000 contracts, one-trade packages and trade packages that take longer than 21 days to execute.[88]

Sequences of individual trades for each contract are classified as packages if they are executed (i) from the same account, (ii) in the same direction (e.g. buy trades), and (iii) successively without a one-day trading break. These criteria are consistent with Frino and Oetomo (2005) and imply that an institution's

[87] Frino and McKenzie (2002) find increased activity, declining spreads, and lower market impact costs in the period before contract maturity. These trades are removed from the sample to alleviate any bias associated with rolling over contracts.
[88] These sample restrictions are consistent with Frino and Oetomo (2005). Trades by locals are excluded to proxy for institutional trades.

order execution is complete when it (i) begins trading in the opposite direction, or (ii) stays out of the market in that contract for more than one trading day.

Table 4-1 presents descriptive statistics for the sample of trades in stock index and interest rate futures contracts examined in this chapter. Panel A reports statistics for individual trades, and Panel B reports statistics for trade packages. For individual trades, there are 153,578 buy trades and 156,133 sell trades in 90-day BAB futures; 455,991 buy trades and 471,320 sell trades in 3-year bond futures; 460,085 buy trades and 464,067 sell trades in 10-year bond futures; and 1,629,367 buy trades and 1,586,000 sell trades in SPI 200 stock index futures. For trade packages, there are 25,228 buy and 24,905 sell packages in 90-day BAB futures; 78,400 buy and 80,609 sell packages in 3-year bond futures; 73,072 buy and 74,265 sell packages in 10-year bond futures; and 266,575 buy and 259,322 sell packages in SPI 200 stock index futures.

Panel A of Table 4-1 reports characteristics of individual trades for all contracts. The average volume for individual trades ranges from 3.89 contracts for sales of SPI 200 futures to 55.61 contracts for purchases of 90-day BAB futures. The characteristics of trade packages are reported in Panel B of Table 4-1. The average number of trades in a package ranges from 5.83 trades for purchases of 3-year bond futures to 6.81 trades for purchases of 10-year bond futures, and the average package volume ranges from 23.97 contracts for sales of SPI 200 futures to 336.61 contracts for purchases of 90-day BAB futures.

Table 4-1
Descriptive statistics

This table reports descriptive statistics for all four contracts examined in Chapter 4. These contracts are 90-day BAB futures, 3-year bond futures, 10-year bond futures and SPI 200 futures. Panel A reports statistics for individual trades, and Panel B reports statistics for trade packages. The mean, median and standard deviation is reported for volume traded and no. of trades. In Panel A, volume traded is the average individual trade volume. In Panel B, volume traded is the average total volume of trade packages and no. of trades is the average number of trades taken to execute a trade package.

		90-day BAB futures		3-year bond futures		10-year bond futures		SPI200 futures	
		Buy	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: Single Trades									
Volume traded	Mean	55.61	52.18	55.41	54.76	17.57	17.47	3.95	3.89
	Median	15.00	13.00	19.00	19.00	5.00	5.00	2.00	2.00
	Std dev	102.37	97.00	132.00	133.78	57.48	56.21	12.60	10.90
Number		153,578	156,133	455,991	471,320	460,085	464,067	1,629,367	1,586,000
Panel B: Trade Packages									
Volume traded	Mean	336.61	332.20	322.41	327.85	118.37	117.98	23.98	23.97
	Median	184.00	181.00	159.00	160.00	47.00	46.00	10.00	10.00
	Std dev	515.15	520.52	535.33	555.50	246.55	244.67	74.22	74.30
No. of trades	Mean	6.10	6.27	5.83	5.86	6.81	6.75	6.12	6.12
	Median	4.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00
	Std dev	9.36	9.77	8.07	8.33	11.62	11.65	13.42	13.09
Number		25,228	24,905	78,400	80,609	73,072	74,265	266,575	259,322

4.2.2 Institutional detail

This chapter examines the four most liquid contracts traded on the SFE: 90-day BAB futures, 3-year bond futures, 10-year bond futures, and SPI 200 stock index futures. The SPI 200 futures contract is written on the S&P/ASX 200, the benchmark Australian equity market index. Traders on the SFE utilise a fully automated trading system, the Sydney Computerised Market (SYCOM). In 1999, the SFE moved from floor to electronic trading and SYCOM moved from being an overnight trading facility to serving as the primary trading platform. Additional details for each contract are provided in Table 4-2.

Table 4-2
Contract specifications

This table reports contract specifications for each futures contract examined in Chapter 4.

	90-day BABs	3-year bonds	10-year bonds	SPI 200
Futures type	Interest rate	Interest rate	Interest rate	Stock index
Settlement month	Mar/Jun/Sept/ Dec up to 20 quarters ahead.	Mar/Jun/Sept/ Dec up to two quarter months ahead.	Mar/Jun/Sept/ Dec up to two quarter months ahead.	Mar/Jun/Sept /Dec up to six quarters ahead.
Minimum price movement	0.01%	0.01% **	0.005%	One index point
Trading hours (US daylight savings time)*	17.08 – 7.00 & 8.28 – 16.30	17.10 – 7.00 & 8.30 – 16.30	17.12 – 7.00 & 8.32 – 16.30	17.10 – 7.00 & 9.50 – 16.30
Trading hours (US non-daylight savings time)*	17.08 – 7.30 & 8.28 – 16.30	17.10 – 7.30 & 8.30 – 16.30	17.12 – 7.30 & 8.32 – 16.30	17.10 – 8.00 & 9.50 – 16.30

Source: Sydney Futures Exchange

***** All times are Sydney times unless otherwise indicated and US daylight saving begins first Sunday in April and ends last Sunday in October.

******The SFE has just introduced new minimum tick requirements for 3-year bonds. The minimum tick reported here is the one relevant to the sample period for this study. There were no minimum tick changes for any contracts during the sample period for this study.

4.3 Research design

Price impact is calculated in the same manner for single trades and trade packages. The measures of price impact and its components employed in Frino and Oetomo (2005) are used in this chapter and are analogous to the measures in Berkman et al. (2005). *Total* price effects capture the total price impact of a trade, and can be decomposed into temporary and permanent price effects. *Temporary* price effects (price reversal) capture the liquidity cost incurred by trades, whereas *Permanent* price effects capture their information content. These variables are defined as follows:

$$Total_i = \frac{(Price_i - OpeningPrice_i)}{MinTick_j} \tag{4-1}$$

$$Temporary_i = \frac{(ClosingPrice_i - Price_i)}{MinTick_j} \tag{4-2}$$

$$Permanent_i = \frac{(ClosingPrice_i - OpeningPrice_i)}{MinTick_j} \tag{4-3}$$

For each individual trade, *opening price* is the first trade during daytime trading hours on the day of the trade, *closing price* is the last trade during daytime trading hours on the day of the trade, and *price* is the trade price. For each trade package, *opening price* is the first trade during daytime trading hours on the first day of the package, *closing price* is the last trade during daytime trading hours on the last day of the package, and *price* is the volume-weighted average price of the package. For both individual trades and trade packages, $MinTick_j$ is the minimum tick for contract j.[89]

The calculation of *Total*, *Temporary*, and *Permanent* for individual trades (trade packages) permits testing of hypothesis $H_{4,1}$ ($H_{4,2}$). To test hypothesis $H_{4,3}$, the pre-and post-trade benchmarks for trade package i are applied to each individual trade that belongs to that package.

To test these three hypotheses, individual trades and trade packages are sorted into mutually exclusive quartiles based on volume. Group 1 includes the smallest trades and group 4 includes the largest trades. A difference of means test is conducted at the five per cent level to determine if the average total, temporary and permanent price effects are significantly different from zero.[90]

4.4 Empirical results: Packages and individual trades

Total, temporary, and permanent price effects for trade *packages* are reported for each size group and for the entire sample of trade packages in Table 4-3. For all contracts, the total price effects reported in Table 4-3 increase monotonically as the trade package size increases. Further, the total price effect for all contracts is statistically significant for large trade packages, and for SPI 200 futures and 3-year bond futures it is also significant for some

[89] Table 4-2 contains the minimum tick for each contract. Price impact is measured in minimum ticks (points), consistent with futures market research.

[90] Chapter 4 utilises a large sample, and therefore it is necessary to adjust the critical level for t values to mitigate Lindley's paradox. Refer to footnote 8 in Chapter 3 for a discussion of the adjustment made.

medium-sized packages. These findings are consistent with those of Frino and Oetomo (2005). Table 4-3 shows no evidence of a statistically significant permanent price effect for trade packages of all sizes, consistent with the prediction of hypothesis $H_{4,1}$. The price impact incurred when trading packages of futures contracts is entirely a liquidity effect, as every size group that incurs significant price impact is accompanied by a significant price reversal.[91] These results are also consistent with those of Frino and Oetomo (2005) and are consistent with the notion that trades executed in futures markets do not contain information.[92]

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[91] Several additional tests are conducted to confirm the results presented in Table 4-3. The results from these tests are presented in Section 4.6.

[92] The consistency of the results in Table 4-3 with those of Frino and Oetomo (2005) suggests that trade package results are not sample-specific. The data set used in this Chapter incorporates the data in Frino and Oetomo (2005) as well as an additional one and a half years of data.

Table 4-3
Total, temporary, and permanent price effects for trade packages

This table reports price effects for trade packages. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening price on the day the package commences to the volume-weighted average price of the package. *Temporary* is the return from the volume-weighted average price of the package to the closing price on the last day of the package. *Permanent* is the return from the opening price on the first day of the package to the closing price on the last day of the package. All returns are measured in ticks. Buy and sell packages are assigned to mutually exclusive quartiles based on volume. Groups 1and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. Contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (25,228 buys; 24,905 sells)							
1	2-67	0.024	-0.013	-0.068	0.102	-0.044	0.089
2	68-185	0.058	-0.071	-0.072	0.011	-0.014	-0.060
3	186-400	0.084	-0.127	-0.051	0.060	0.033	-0.067
4	401-9000	0.228*	-0.218*	-0.139*	0.094*	0.089	-0.124
	All Packages	0.098*	-0.105*	-0.082*	0.066*	0.016	-0.039
Panel B: 3-year bonds (78,400 buys; 80,609 sells)							
1	2-65	-0.113*	0.001	0.026	0.062	-0.087	0.063
2	66-160	-0.090	-0.022	0.058	0.005	-0.032	-0.017
3	161-354	0.013	-0.131*	0.020	0.076	0.033	-0.055
4	355-10000	0.197*	-0.184*	-0.081*	0.110*	0.116	-0.074
	All Packages	0.000	-0.084*	0.006	0.064*	0.006	0.020
Panel C: 10-year bonds (73,072 buys; 74,265 sells)							
1	2-16	-0.074	-0.039	0.001	-0.027	-0.073	-0.066
2	17-47	0.073	-0.142	-0.027	0.058	0.046	-0.084
3	48-113	0.086	-0.148	-0.080	0.056	0.006	-0.092
4	114-7000	0.221*	-0.245*	-0.197*	0.200*	0.024	-0.045
	All Packages	0.076	-0.145*	-0.075*	0.071*	0.001	-0.074
Panel D: SPI 200 (266,575 buys; 259,322 sells)							
1	2-5	0.131	0.032	-0.030	-0.093	0.101	-0.061
2	6-10	0.266	-0.235	-0.024	0.353*	0.242	0.118
3	11-21	0.674*	-0.325*	-0.610*	0.351*	0.064	0.026
4	22-6000	1.020*	-0.661*	-0.669*	0.566*	0.351	-0.095
	All Packages	0.497*	-0.272*	-0.312*	0.262*	0.185	-0.010

***** Significantly different from zero at the 5% level

Table 4-4
Total, temporary and permanent price effects for individual trades

This table reports price effects for individual trades. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening price on the day of the trade to the trade price. *Temporary* is the return from the trade price to the closing price on the day of the trade. *Permanent* is the return from the opening price on the day of the trade to the closing price on the day of the trade. All returns are measured in ticks. Buy and sell single trades are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (153,578 buys; 156,133 sells)							
1	1-4	0.372*	-0.304*	-0.076*	0.174*	0.296*	-0.130*
2	5-15	0.420*	-0.513*	-0.102*	0.027	0.318*	-0.486*
3	16-66	0.330*	-0.480*	-0.136*	0.015	0.195*	-0.465*
4	67-3000	0.090*	-0.104*	-0.101*	0.076*	-0.011	-0.028
	All Trades	0.302*	-0.348*	-0.103*	0.076*	0.199*	-0.272*
Panel B: 3-year bonds (455,991 buys; 471,320 sells)							
1	1-5	0.085*	-0.366*	-0.008	0.082*	0.077*	-0.284*
2	6-19	0.173*	-0.437*	-0.037*	0.093*	0.136*	-0.344*
3	20-56	0.069*	-0.274*	0.000	0.047*	0.069*	-0.227*
4	57-2000	0.028	-0.056*	-0.030*	0.087*	-0.002	0.031
	All Trades	0.088*	-0.282*	-0.017*	0.076*	0.071*	-0.206*
Panel C: 10-year bonds (460,085 buys; 464,067 sells)							
1	1-1	0.200*	-0.525*	-0.026	0.080*	0.174*	-0.445*
2	2-5	0.441*	-0.716*	-0.186*	0.099*	0.255*	-0.617*
3	6-16	0.206*	-0.397*	-0.038	0.030	0.168*	-0.367*
4	17-6500	0.082*	-0.114*	-0.117*	0.091*	-0.035	-0.023
	All Trades	0.227*	-0.440*	-0.088*	0.077*	0.139*	-0.363*
Panel D: SPI 200 (1,629,367 buys; 1,586,000 sells)							
1	1-1	0.655*	-0.257*	-0.384*	0.205*	0.271*	-0.052
2	2-2	0.728*	-0.492*	-0.471*	0.182*	0.257*	-0.310*
3	3-5	0.693*	-0.532*	-0.453*	0.257*	0.240*	-0.275*
4	5-4500	0.492*	-0.355*	-0.355*	0.299*	0.137	-0.056
	All Trades	0.646*	-0.371*	-0.407*	0.229*	0.239*	-0.142*

***** Significantly different from zero at the 5% level

Table 4-4 reports total, temporary, and permanent price effects for *individual* trades. To ensure consistency with Berkman et al. (2005) and Kurov (2005), Table 4-4 also reports the mean total, temporary, and permanent price effects for all trades irrespective of size. Across all four contracts, the total price effects in Table 4-4 are largest for medium-sized trades (groups 2 and 3). This is consistent with the results reported by Barclay and Warner (1993) and Chakravarty (2001).

In Table 4-4, small- and medium-sized trades have a statistically significant permanent price effect. Importantly, the overall permanent price effect for each contract in Table 4-4 is statistically significant, suggesting that these single trades are executed by informed traders and contain information. This is consistent with Berkman et al. (2005) and Kurov (2005) and directly contradicts the results reported in Table 4-3 for trade packages (as well as the results reported in Frino and Oetomo (2005) for trade packages). The results presented in Table 4-4 are also consistent with hypothesis $H_{4,2}$, which predicts that individual trades that belong to trade packages are associated with a permanent price effect.

The sample and methodology employed in Chapter 4 of this dissertation differ from Berkman et al. (2005) and Kurov (2005); however, the results are consistent with both studies. Hence, it is possible to eliminate sample and methodological differences as an explanation for the conflicting findings.

This section provides evidence that institutional trade packages in futures markets do not contain information. However, when trades that belong to these packages are analysed individually, there is a statistically significant permanent effect on prices. As the conflicting results are not attributable to sample or methodological differences and are consistent with earlier studies, an insight provided by Chan and Lakonishok (1995) may explain these contradictory findings. Chan and Lakonishok (1995) argue that it is 'misleading' to analyse individual trades in price impact studies as institutions execute large orders by breaking them up into a sequence of smaller trades. The execution of successive trades in a package generates price pressure in the market and appears to produce a permanent price effect bias when trades that belong to packages are examined individually. The following section examines total, temporary, and permanent price effects of single trades after controlling for this bias.

4.5 Empirical results: A re-examination of individual trades

One implication of the rationale provided by Chan and Lakonishok (1995) is that any price reversal, which is likely to be associated with the execution of a package, will not occur until *after* the entire package is executed. To test this implication and to correct for this possible bias in individual trades, the following analysis redefines benchmarks for individual trades. Specifically, it applies trade package benchmarks to the individual trades in each package. This produces a measure of the permanent price effect unaffected by the price pressure associated with the completion of an individual trade's respective trade package. To implement this analysis, the variables in Eq. (4-1) to Eq. (4-3) for individual trades are redefined; $Price_i$ remains the trade price, $OpeningPrice_i$ is now the opening price on the first day of the package to which the trade belongs, and $ClosingPrice_i$ is now the closing price on the last day of the package to which the trade belongs. Table 4-5 reports the results for this analysis.

In Table 4-5, the total and temporary price effects are statistically significant, consistent with the individual trade analysis in Table 4-4. In contrast, the statistical significance of the permanent price effect changes considerably between Tables 4-4 and 4-5. Individual trades in Table 4-4 incur overall significant permanent price effects, whereas individual trades in Table 4-5 incur no significant permanent price effects. Redefining the post-trade benchmark for an individual trade to coincide with the completion of that trade's package produces no evidence of a statistically significant permanent price effect. The results for individual trades in Table 4-5 are now consistent with results for trade packages reported in this study and also in Frino and Oetomo (2005), and confirm the central prediction of hypothesis $H_{4,3}$.

Table 4-5
Total, temporary and permanent price effects for individual trades: Implementing trade package benchmarks

This table reports price effects for individual trades using trade package benchmarks. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening price on the first day of the package to the individual trade price. *Temporary* is the return from the individual trade price to the closing price on the last day of the package. *Permanent* is the return from the opening price on the first day of the package to the closing price on the last day of the package. All returns are measured in ticks. Buy and sell single trades are assigned to mutually exclusive quartiles based on volume. Groups 1and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (153,578 buys; 156,133 sells)							
1	1-4	0.447*	-0.288*	-0.433*	0.287*	0.014	-0.001
2	5-15	0.515*	-0.524*	-0.512*	0.486*	0.003	-0.039
3	16-66	0.344*	-0.430*	-0.304*	0.434*	0.041	0.004
4	67-3000	0.111*	-0.108*	-0.137*	0.119*	-0.026	0.012
	All Trades	0.347*	-0.327*	-0.340*	0.322*	0.008	-0.005
Panel B: 3-year bonds (455,991 buys; 471,320 sells)							
1	1-5	0.257*	-0.327*	-0.246*	0.286*	0.011	-0.041
2	6-19	0.323*	-0.480*	-0.298*	0.438*	0.025	-0.041
3	20-56	0.142*	-0.279*	-0.127*	0.266*	0.015	-0.012
4	57-2000	0.094*	-0.117*	-0.062*	0.116*	0.032	-0.002
	All Trades	0.199*	-0.289*	-0.179*	0.266*	0.020	-0.024
Panel C: 10-year bonds (460,085 buys; 464,067 sells)							
1	1-1	0.160*	-0.633*	-0.113*	0.633*	0.048	0.000
2	2-5	0.600*	-0.779*	-0.627*	0.805*	-0.027	0.026
3	6-16	0.197*	-0.468*	-0.198*	0.484*	-0.001	0.017
4	17-6500	0.113*	-0.346*	-0.169*	0.394*	-0.056	0.048
	All Trades	0.247*	-0.561*	-0.250*	0.582*	-0.002	0.021
Panel D: SPI 200 (1,629,367 buys; 1,586,000 sells)							
1	1-1	0.579*	-0.172*	-0.484*	0.236*	0.096	0.064
2	2-2	0.653*	-0.434*	-0.567*	0.373*	0.086	-0.060
3	3-5	0.607*	-0.515*	-0.575*	0.502*	0.032	-0.013
4	5-4500	0.357*	-0.311*	-0.376*	0.171*	-0.018	-0.139
	All Trades	0.558*	-0.312*	-0.498*	0.304*	0.061	-0.008

***** Significantly different from zero at the 5% level

The disparity in results between Tables 4-4 and 4-5 suggests that the price pressure associated with the execution of successive trades in a trade package is contributing to the observed permanent price effect in individual trades reported in Table 4-4. The price reversal now following trade packages (Table 4-3) and individual trades (Table 4-5) suggests that institutional transactions in futures markets do not convey information.

4.6 Additional tests

This section discusses various robustness tests employed to confirm results presented in Section 4.3 and Section 4.4. These tests include utilising mid-quotes instead of transaction prices, analysing the largest five per cent of trade packages, and re-forming packages using different criteria.

The measures of total, temporary, and permanent price effects described in Eq. (4-1) to Eq. (4-3) use transaction prices in their estimation. As discussed in Chapter 3, there is potential bid-ask bias when using transaction prices to measure price impact. To avoid this bias, the total, temporary, and permanent price effects are recalculated using prevailing quote midpoints. In Eq. (4-1) to Eq. (4-3), every transaction price is replaced with the quote midpoint immediately before the benchmark trades. Table 4-6 presents these results for trade packages, Table 4-7 for individual trades, and Table 4-8 for individual trades with trade package benchmarks. For both individual trades and trade packages, the results using quote midpoints are consistent with transaction price results.

Table 4-6
Total, temporary, and permanent price effects for trade packages: Quote midpoint returns

This table reports price effects for trade packages. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening mid-quote on the day the package commences to the volume-weighted average price of the package. *Temporary* is the return from the volume-weighted average price of the package to the closing mid-quote on the last day of the package. *Permanent* is the return from the opening mid-quote on the first day of the package to the closing mid-quote on the last day of the package. All returns are measured in ticks. Buy and sell packages are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (25,228 buys; 24,905 sells)							
1	2-67	0.033	-0.002	-0.078	0.089	-0.045	0.087
2	68-185	0.084	-0.081	-0.058	0.104	0.026	0.023
3	186-400	0.156	-0.094	-0.128*	0.076*	0.028	-0.018
4	401-9000	0.254*	-0.217*	-0.110*	0.076*	0.144	-0.141
	All Packages	0.123*	-0.089	-0.091*	0.088*	0.032	-0.001
Panel B: 3-year bonds (78,400 buys; 80,609 sells)							
1	2-65	0.085	-0.113	-0.102	0.067	-0.016	-0.046
2	66-160	0.261*	-0.255*	-0.298*	0.193*	-0.037	-0.062
3	161-354	0.580*	-0.349*	-0.353*	0.254*	0.227	-0.095
4	355-10000	1.091*	-0.682*	-0.989*	0.590*	0.102	-0.092
	All Packages	0.478*	-0.335*	-0.415*	0.264*	0.063	-0.071
Panel C: 10-year bonds (73,072 buys; 74,265 sells)							
1	2-16	-0.036	-0.094	0.046	0.113	0.010	0.019
2	17-47	0.069	-0.129	-0.005	0.039	0.064	-0.090
3	48-113	0.123	-0.146	-0.159	0.122*	-0.036	-0.024
4	114-7000	0.241*	-0.225*	-0.109*	0.156*	0.132	-0.069
	All Packages	0.094	-0.146*	-0.053*	0.106*	0.041	-0.040
Panel D: SPI 200 (266,575 buys; 259,322 sells)							
1	2-5	-0.128	-0.011	0.031	0.021	-0.097	0.010
2	6-10	-0.091	-0.051	0.027	0.047	-0.064	-0.004
3	11-21	0.114	-0.124*	-0.078	0.055	0.036	-0.069
4	22-6000	0.204	-0.211*	-0.158	0.103*	0.046	-0.108
	All Packages	0.478*	-0.146*	-0.415*	0.106*	0.063	-0.040

***** Significantly different from zero at the 5% level

Table 4-7
Total, temporary and permanent price effects for individual trades: Quote midpoint returns

This table reports price effects for individual trades. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening mid-quote on the day of the trade to the trade price. *Temporary* is the return from the trade price to the closing mid-quote on the day of the trade. *Permanent* is the return from the opening mid-quote on the day of the trade to the closing mid-quote on the day of the trade. All returns are measured in ticks. Buy and sell single trades are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (153,578 buys; 156,133 sells)							
1	1-4	0.577*	-0.458*	-0.150*	0.097*	0.427*	-0.361*
2	5-15	0.489*	-0.379*	-0.120*	0.050*	0.369*	-0.329*
3	16-66	0.200*	-0.315*	-0.153*	0.040*	0.047*	-0.275*
4	67-3000	0.077	-0.074	-0.135*	0.063	-0.058	-0.011
	All Trades	0.335*	-0.316*	-0.140*	0.063*	0.195*	-0.253*
Panel B: 3-year bonds (455,991 buys; 471,320 sells)							
1	1-5	0.046*	-0.420*	-0.007	0.100*	0.039	-0.320*
2	6-19	0.217*	-0.429*	-0.069*	0.134*	0.148*	-0.295*
3	20-56	0.065*	-0.291*	-0.019	0.067*	0.046*	-0.224*
4	57-2000	0.053*	-0.124*	-0.081*	0.021	-0.028	-0.103*
	All Trades	0.086*	-0.320*	-0.039*	0.080*	0.047*	-0.240*
Panel C: 10-year bonds (460,085 buys; 464,067 sells)							
1	1-1	0.214*	-0.546*	-0.042	0.016	0.172*	-0.530*
2	2-5	0.623*	-0.831*	-0.110*	0.012	0.513*	-0.819*
3	6-16	0.295*	-0.302*	-0.129*	0.007	0.166*	-0.295*
4	17-6500	0.162*	-0.061	-0.170*	0.001	-0.008	-0.060
	All Trades	0.347*	-0.451*	-0.112*	0.010	-0.235*	-0.441*
Panel D: SPI 200 (1,629,367 buys; 1,586,000 sells)							
1	1-1	0.355*	-0.447*	-0.001*	0.199*	0.354*	-0.248*
2	2-2	0.546*	-0.594*	-0.157*	0.114*	0.389*	-0.480*
3	3-5	0.503*	-0.523*	-0.193*	0.182*	0.310*	-0.341*
4	5-4500	0.122	-0.315*	-0.127*	0.276*	-0.005	-0.039
	All Trades	0.375*	-0.463*	-0.088*	0.195*	0.287*	-0.268*

***** Significantly different from zero at the 5% level

Table 4-8
Total, temporary and permanent price effects for individual trades: Implementing trade package benchmarks and quote midpoint returns

This table reports price effects for individual trades using trade package benchmarks. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening mid-quote on the first day of the package to the individual trade price. *Temporary* is the return from the individual trade price to the closing mid-quote on the last day of the package. *Permanent* is the return from the opening mid-quote on the first day of the package to the closing mid-quote on the last day of the package. All returns are measured in ticks. Buy and sell single trades are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (153,578 buys; 156,133 sells)							
1	1-4	0.375*	-0.363*	-0.463*	0.369*	-0.088	0.006
2	5-15	0.549*	-0.446*	-0.411*	0.386*	0.138	-0.060
3	16-66	0.230*	-0.404*	-0.146*	0.338*	0.084	-0.066
4	67-3000	0.186*	-0.082	-0.162*	0.103*	0.024	0.021
	All Trades	0.338*	-0.328*	-0.299*	0.303*	0.039	-0.025
Panel B: 3-year bonds (455,991 buys; 471,320 sells)							
1	1-5	0.191*	-0.462*	-0.212*	0.479*	-0.021	0.017
2	6-19	0.319*	-0.528*	-0.240*	0.501*	0.079	-0.027
3	20-56	0.076*	-0.270*	-0.095*	0.252*	-0.019	-0.018
4	57-2000	0.061*	-0.101*	-0.113*	0.107*	-0.052	0.006
	All Trades	0.155*	-0.339*	-0.164*	0.335*	-0.009	-0.004
Panel C: 10-year bonds (460,085 buys; 464,067 sells)							
1	1-1	0.304*	-0.529*	-0.261*	0.479*	0.043	-0.050
2	2-5	0.428*	-0.993*	-0.443*	0.814*	-0.015	-0.179
3	6-16	0.148*	-0.224*	-0.104*	0.211*	0.044	-0.013
4	17-6500	0.129*	-0.147*	-0.199*	0.235*	-0.070	0.088
	All Trades	0.258*	-0.483*	-0.255*	0.443*	0.003	-0.040
Panel D: SPI 200 (1,629,367 buys; 1,586,000 sells)							
1	1-1	0.571*	-0.444*	-0.614*	0.445*	-0.043	0.001
2	2-2	0.750*	-0.615*	-0.753*	0.441*	-0.003	-0.174
3	3-5	0.692*	-0.570*	-0.784*	0.552*	-0.092	-0.018
4	5-4500	0.199*	-0.483*	-0.270*	0.555*	-0.071	0.072
	All Trades	0.560*	-0.505*	-0.611*	0.486*	-0.051	-0.019

***** Significantly different from zero at the 5% level

The second test examines the robustness of results to the effects of extremely large trade packages. Specifically, the second test investigates whether permanent price effects are associated with the largest five per cent of trade packages. The results from the second test are presented in Table 4-9. In Table 4-9, the largest five per cent of trade packages in all contracts are not associated with a statistically significant permanent price effect, providing evidence that extremely large trade packages are executed by uninformed traders and do not convey information. These results are consistent with results in Table 4-3, and show that results documented in Section 4.4 are robust to the presence of extremely large packages.

Table 4-9
Total, temporary, and permanent price effects for the largest five per cent of trade packages

This table reports price effects for the largest five per cent of trade packages for each of the contracts examined in this chapter – 90-day BAB futures, 3-year bond futures, 10-year bond futures and SPI 200 futures. *Total* is the return from the opening price on the day the package commences to the volume-weighted average price of the package. *Temporary* is the return from the volume-weighted average price of the package to the closing price on the last day of the package. *Permanent* is the return from the opening price on the first day of the package to the closing price on the last day of the package. All returns are measured in ticks. Buy and sell packages are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
	No. Contracts	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
90-day BABs	> 1200	0.350*	-0.334*	-0.151*	0.122*	0.199	-0.212
3-year bonds	> 1016	0.203*	-0.257*	-0.184*	0.147*	0.019	-0.110
10-year bonds	> 1016	0.291*	-0.310*	-0.117*	0.150*	0.174	-0.160
SPI 200	> 1018	1.156*	-0.755*	-0.936*	0.404*	0.220	-0.351

***** Significantly different from zero at the 5% level

The final test re-forms trade packages by aggregating trades executed by the same institution on the same day. Previously, the packaging criteria aggregated trades executed by the same institution successively without a one-day trading break. This adjustment provides a check of the trade package criteria. Table 4-10 reports the results from this final test, and indicates that results are robust to the packaging criteria.

Table 4-10
Total, temporary, and permanent price effects for trade packages: Re-forming trade packages

This table reports price effects for trade packages formed by aggregating trades executed by the same institution on the same day. Panel A reports results for 90-day BAB futures, Panel B reports 3-year bond futures, Panel C reports 10-year bond futures and Panel D reports SPI 200 futures. *Total* is the return from the opening price on the day the package commences to the volume-weighted average price of the package. *Temporary* is the return from the volume-weighted average price of the package to the closing price on the last day of the package. *Permanent* is the return from the opening price on the first day of the package to the closing price on the last day of the package. All returns are measured in ticks. Buy and sell packages are assigned to mutually exclusive quartiles based on volume. Groups 1 and 4 represent the smallest and largest groups, respectively. A *t*-test adjusted for sample size is used to test the deviation of mean values from zero.

		Total		Temporary		Permanent	
Size	*No. contracts*	*Buy*	*Sell*	*Buy*	*Sell*	*Buy*	*Sell*
Panel A: 90-day BABs (25,228 buys; 24,905 sells)							
1	2-67	0.075	-0.092	-0.082	0.077	-0.007	-0.015
2	68-185	0.091	-0.095	-0.071	0.022	0.020	-0.073
3	186-400	0.102	-0.135	-0.034	0.050	0.068	-0.085
4	401-9000	0.209*	-0.228*	-0.112*	0.089*	0.097	-0.139
	All Packages	0.115*	-0.136*	-0.080*	0.057*	0.035	-0.079
Panel B: 3-year bonds (78,400 buys; 80,609 sells)							
1	2-65	-0.048	-0.049	-0.011	0.085	-0.058	0.036
2	66-160	0.072	-0.068	-0.007	0.007	0.065	-0.061
3	161-354	0.127*	-0.159*	-0.024	0.042	0.103	-0.117
4	355-10000	0.140*	-0.246*	-0.156*	0.135*	-0.016	-0.111
	All Packages	0.089*	-0.133*	-0.052*	0.071*	0.037	0.062
Panel C: 10-year bonds (73,072 buys; 74,265 sells)							
1	2-16	-0.041	0.054	-0.052	-0.034	-0.093	0.020
2	17-47	-0.019	-0.030	-0.036	0.038	-0.055	0.008
3	48-113	0.049	-0.154*	-0.096	0.104*	-0.047	-0.050
4	114-7000	0.253*	-0.342*	-0.282*	0.240*	-0.029	-0.102
	All Packages	0.071*	-0.124*	-0.119*	0.067*	-0.048	-0.057
Panel D: SPI 200 (266,575 buys; 259,322 sells)							
1	2-5	0.060	0.057	-0.045	-0.063	0.015	-0.006
2	6-10	0.234	-0.189	-0.068	0.298*	0.166	0.109
3	11-21	0.607*	-0.303*	-0.588*	0.293*	0.019	-0.010
4	22-6000	0.934*	-0.590*	-0.723*	0.397*	0.211	-0.193
	All Packages	0.463*	-0.278*	-0.345*	0.257*	0.118	-0.021

***** Significantly different from zero at the 5% level

4.7 Summary

Using a proprietary data set from the Sydney Futures Exchange, Chapter 4 reconciles an inconsistency in futures microstructure literature. Berkman et al. (2005) and Kurov (2005) examine single trades in futures markets and find evidence of a permanent price effect, while Frino and Oetomo (2005) examine trade packages and document temporary effects only.

This chapter first examines the price behaviour surrounding trade packages, and finds no evidence of a permanent price effect for trade packages of all sizes. However, if each trade belonging to a trade package is examined individually, the results show a statistically significant permanent effect. To reconcile this inconsistency between packages and individual trades, total, temporary, and permanent effects are re-estimated for individual trades. This involves applying pre- and post-trade benchmarks from the trade package to each individual trade from that package. This analysis produces consistent results for trade packages and individual trades. That is, overall, Chapter 4 finds little evidence that transactions in futures markets contain information.

Chapter 5

The determinants of execution costs in opaque markets

5.1 Introduction

The literature reviewed in Section 2.1.3 attributes the observed negative relation between execution costs and trade size in opaque markets to two factors – information asymmetry (Schultz, 2001, and Harris and Piwowar, 2006) and broker-client relationships (Bernhardt et al., 2005). Chapter 5 contributes to the literature by attempting to disentangle these two factors and determine their relative effects on execution costs in opaque markets.

Studies that document a negative relation between execution costs and trade size encompass several opaque markets, including the US corporate bond market, the US municipal bond market, and the London dealer market. The first hypothesis ($H_{5,1}$) predicts that due to its opaque structure, execution costs decline with trade size in the money market. The next two hypotheses attempt to explain this negative relation. The second hypothesis, the price information hypothesis ($H_{5,2}$), predicts that traders with *ex ante* price information incur lower execution costs than traders with no information. The third hypothesis, the relationship hypothesis ($H_{5,3}$), predicts that traders with strong broker-client relationships incur lower execution costs than traders without established broker relationships. Consistent with results documented in

Schultz (2001), the final hypothesis ($H_{5,4}$) predicts that the price information hypothesis is the dominant factor in determining execution costs in opaque markets.

The remainder of Chapter 5 is organised as follows. Section 5.2 describes the data and sample, and provides institutional detail. Section 5.3 documents the research design. Sections 5.4, 5.5, and 5.6 present the empirical results. Section 5.7 summarises the chapter.

5.2 Data, sample, and institutional detail

5.2.1 Data and sample

Chapter 5 employs a unique money market data set from Austraclear, which provides data for the period 1 August, 2005 to 31 October, 2005.[93] The data capture every transaction in the wholesale money market, and for each transaction report the trade date, security type, face value and deal value, maturity date of the security, and the identity of both the buyer and seller in the transaction. Importantly, the data identify individual traders *within* an institution as well as the institution. The data include transactions in Bank Accepted Bills (BABs) and Negotiable Certificates of Deposit (NCDs).[94]

This chapter extends prior literature by employing methodology previously applied to equity and futures markets. Specifically, the chapter applies the

[93] Section 5.2.2 contains a description of the money market in Australia.
[94] The yield is inferred for each transaction and converted into a price by subtracting the yield from 100, consistent with the pricing convention in this market. Note that the timestamps on the Austraclear data are inaccurate and are not used in this analysis.

trade package methodology developed in Chan and Lakonishok (1995) to the money market data, and estimates execution costs for packages of trades in BABs and NCDs.[95] Trade packages in BABs and NCDs are formed by isolating each individual trader and aggregating their trades on a particular day if (i) the trades are in the same direction, (ii) the trades are in securities with the same maturity year and month, and (ii) the securities mature early month or late month.[96]

Table 5-1 reports summary statistics for trade packages. The sample consists of 2,766 buy packages and 2,499 sell packages of BABs and NCDs. Buy packages have an average notional value of AUD 94.16 million and are executed using approximately 4.85 individual BABs and NCDs; sell packages have an average notional value of AUD 112.13 million and are executed using approximately 5.79 individual BABs and NCDs. Table 5-1 demonstrates that the money market is particularly liquid, with an average of 42.02 buy packages and 37.63 sell packages executed each day. The average yield of both buy and sell packages is 5.62 per cent, representing a slight premium to the cash rate of 5.50 per cent. The cash rate remained unchanged throughout the sample period.

[95] Bessembinder et al. (2006) examine US corporate bonds and document first-order autocorrelation in order flow, suggesting that bond orders could be split into smaller trades.
[96] These criteria were developed through discussions with money market brokers and institutions trading in the money market. When of a similar maturity, BABs and NCDs are perfect substitutes. Institutions trading in the short-term money market will execute trade packages across both BABs and NCDs.

Table 5-1
Descriptive statistics for trade packages

This table reports descriptive statistics for trade packages executed in Bank Accepted Bills (BABs) and Negotiable Certificates of Deposit (NCDs). A trade package of BABs and NCDs is formed by aggregating an institution's trades on a particular day if the trades are in the same direction, the trades are in commercial paper with the same maturity year and month, and the commercial paper matures early month or late month. *Notional value* is the notional value of a trade package in AUD millions, *No. of BABs/NCDs per package* is the number of BABs and/or NCDs taken to execute a trade package, *No. of packages per day* is the number of trade packages executed per trading day, and *Yield* is the yield of the trade package. *N* is the total number of trade packages. Statistics are reported separately for buy and sell trade packages.

		BABs and NCDs	
		Buy	*Sell*
Notional value (AUD '000,000)	Mean	94.16	112.13
	Median	55.00	70.00
	Std Dev	112.03	132.77
No. of BABs/NCDs per package	Mean	4.85	5.79
	Median	3.00	3.00
	Std Dev	5.68	7.14
No. packages per day	Mean	42.02	37.63
	Median	42.00	37.00
	Std Dev	7.71	6.11
Yield (%)	Mean	5.62	5.62
	Median	5.61	5.61
	Std Dev	0.05	0.05
N		2,766	2,499

5.2.2 Institutional detail

The money market in Australia is self-regulated by an industry body, the Australian Financial Markets Association (AFMA). One role of AFMA is to determine which banks have bank bills and certificates of deposit acceptable for inter-bank trades. These banks are referred to as prime banks. The criteria for inclusion as a prime bank are largely qualitative; however, prime banks must have a short-term Standard & Poor's rating of A1+ and a minimum long-term rating of AA-. Commercial paper issued by prime banks trades as a single commodity, with liquidity concentrated around the mid-morning rate set.

There are six prime banks in the money market during the sample period.[97] Prime banks sell their commercial paper to other banks (both prime and non-prime) in the wholesale primary market.[98] Once purchased, commercial paper is either held by an institution until maturity or retraded in the secondary market. Since March 15, 2004, the Reserve Bank of Australia (RBA) has participated in the secondary market, conducting repurchase agreements with eligible banks.

Transactions in the Australian money market are conducted through over-the-counter brokers who facilitate trades but do not act as principal. As compensation for their services, brokers will charge a flat fee per million dollars traded, depending on the maturity of the security. The two major brokers in this market each have a live Reuters feed on which they post bid and ask prices for set quantities of commercial paper across a selection of maturities.[99] Institutional traders will contact a broker and begin negotiations based on these prices.

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[97] The six banks classified as prime banks during the sample period are ANZ Banking Group, BNP Paribas, Citibank, Commonwealth Bank of Australia, National Australia Bank, and Westpac Banking Corporation. Citibank is no longer listed as a prime bank due to a downgrade of its credit rating.

[98] Wholesale transactions represent between 80 per cent and 85 per cent of the total money market in Australia and are the focus of this study. Retail trades represent only a small fraction of the market and are not captured in the Austraclear data.

[99] These quotes are not available for analysis as Reuters do not record them.

There is effectively no pre- or post-trade transparency in the Australian money market. Prior to trading, only the bid and ask quotes of the two brokers are available to institutions. These quotes are indicative at best, as they relate to fixed quantities across different maturities. The final transaction price is determined by negotiation between counterparties and can differ substantially from the quotes on offer, depending on the quantity and maturity of the commercial paper. There is also no post-trade trade transparency in this market. All completed wholesale transactions are reported to Austraclear, a debt clearinghouse, but this information is never released to the market. AFMA report end-of-day reference rates for BABs and NCDs; however, these rates are not market-determined.[100]

5.3 Research design

Execution costs are calculated using methodology analogous to that of Berkowitz, Logue, and Noser (1988). The primary benchmark implemented to measure execution costs is the notional value-weighted average price (VWAP) from the previous day's trading. Berkowitz et al. (1988) and Chan and Lakonishok (1995) identify two potential disadvantages of utilising a VWAP benchmark to measure execution costs – the calculation of a VWAP for illiquid securities and the potential for traders to game the VWAP. These disadvantages do not extend to the analysis presented in this chapter. First, the

[100] At the end of each business day, contributing members submit their BAB/NCD mid-rates for a selection of maturities. These reference rates are provided to allow institutions to price their Australian dollar short-term securities and evaluate their exposure to interest rate risk. As the rates are reported independently, it is possible the AFMA end-of-day reference rates may not reflect the day's trading, as contributing members can submit reference rates in line with their own agenda.

liquidity of the money market mitigates the undue influence of abnormally large transactions on the VWAP.[101] The effects of abnormal trades are further reduced by implementing the VWAP on the previous day as the benchmark, as it represents a benchmark price independent of the trade package. Second, it is not possible to game the VWAP in an opaque market as there is no post-trade price transparency.

The execution cost *(EC)* associated with trade package *i* is estimated as follows:

$$EC_{it} = D_i * (VWAP\ Package_{it} - VWAP_{k,t-1}) * 100, \qquad (5\text{-}1)$$

where D_i is a binary variable that equals 1 if trade package *i* is a buy and -1 if trade package *i* is a sell. $VWAP\ Package_{it}$ is the notional value-weighted average price of trade package *i* on day *t*. $VWAP_{k,t-1}$ is the notional value-weighted average price across the previous day's trading for one of the following four maturity groups *k:* (i) less than or equal to 30 days, (ii) greater than 30 days and less than or equal to 90 days, (iii) greater than 90 days and less than or equal to 180 days, and (iv) greater than 180 days. Each trade package is matched with an appropriate benchmark for its maturity.[102] All execution costs are reported in basis points. To assert the robustness of the

[101] On average, 324 BABs and NCDs are traded each day.
[102] The first three groups represent approximately 30 per cent of the sample each, and the final group represents approximately 10 per cent of the sample.

results, each table reports results using both the VWAP on day *t-1* and the VWAP on day *t* as the benchmark price.

5.4 Empirical results: Execution costs and trade size

To examine the variation in execution costs with trade package size, trade packages are separated into mutually exclusive quintiles based on their notional value. Results are reported for two benchmarks: the VWAP from the previous day's trading ($VWAP_{t-1}$) and the VWAP from the day's trading ($VWAP_t$). This section also examines whether buy packages and sell packages incur execution costs of a similar magnitude. These results are reported in Table 5-2.

Table 5-2
Average execution costs for trade packages as determined by trade size

This table presents average execution costs for trade packages of BABs and NCDs. Trade packages are ranked by notional value and sorted into five mutually exclusive size quintiles. Group 1 contains the smallest trade packages, and Group 5 contains the largest trade packages. Execution costs are measured (i) as the difference between the value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and (ii) as the difference between the VWAP of the trade package and the matched VWAP on the day ($VWAP_t$). Execution costs are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. Abs(buys) – Abs(sells) is the absolute difference in execution costs for buy and sell packages. All execution costs are reported in basis points and *t*-statistics are reported in parentheses.

		Average execution costs (bps)					
		$VWAP_{t-1}$		$VWAP_t$		Abs (buys) – Abs (sells)	
	Notional value ('000,000)	*Buys*	*Sells*	*Buys*	*Sells*	$VWAP_{t-1}$	$VWAP_t$
1	0 – 18.99	0.776**	0.814**	0.686**	1.040**	-0.038	-0.353
2	19 – 39.99	0.558**	0.671**	0.605**	0.572**	-0.113	0.033
3	40 – 69.99	0.509**	0.342*	0.464**	0.254	0.167	0.209
4	70 – 139.99	0.135	0.262	0.099	0.193	-0.127	-0.094
5	> 140	-0.252	-0.048	-0.224*	-0.060	0.205	0.164

* Significantly different from zero at the 5% level ** Significantly different from zero at the 1 % level

For both buy and sell trade packages in Table 5-2, execution costs estimated using the $VWAP_{t-1}$ benchmark decline monotonically as the notional value of the trade package increases.[103] This observed negative relation between execution costs and trade package size is consistent with hypothesis $H_{5,1}$ and previous studies of opaque markets. In addition, average execution costs are negative for the group containing the largest buy and sell trade packages. This implies that traders buying or selling extremely large packages of BABs and NCDs on average transact at a better price than the VWAP on the previous day. This finding is consistent with prior literature, as the total cost function reported in Harris and Piwowar (2006) is negative for the largest trades, and Green et al. (2007a) find that dealers more often lose money on large trades than small trades.

Table 5-2 also reports that there is no statistically significant difference in average execution costs across buy and sell trade packages. This holds for both benchmarks, demonstrating that buy and sell trade packages incur execution costs of a similar magnitude. The similar magnitude and direction of execution costs for buy and sell trade packages obviates the need to examine them separately. From this point forward, this chapter examines buy and sell trade packages jointly.

To provide an initial characterisation of execution costs across traders, this section also examines the distribution of execution costs across all traders in

[103] Using the $VWAP_t$ benchmark produces similar results.

the sample.[104] Results are reported in Table 5-3. There is substantial dispersion in execution costs across the 108 traders examined in this chapter. Table 5-3 reports that execution costs measured across traders using the $VWAP_{t-1}$ benchmark have a standard deviation of approximately 2.76 basis points and there is a 5.96 basis point difference between the top and bottom 10 per cent of traders. These figures represent a substantial variation in execution costs relative to the mean, approximately three and six times respectively, and warrant further investigation.[105]

[104] These are individual traders, not institutions. Some institutions have more than one trader in the money market.

[105] Chan and Lakonishok (1995) conduct a comparable analysis of money managers in the equity market and find a similar dispersion in execution costs – a standard deviation of approximately two and a half times the mean.

Table 5-3
The distribution of execution costs across all traders in the money market

This table describes the distribution of execution costs across the 108 traders in the sample. Execution costs are calculated for each trade package, and average execution costs are calculated across all packages executed by each of the 108 traders in the sample. Buy and sell trade packages are included in the analysis.

	Execution costs (bps)	
	$VWAP_{t-1}$	$VWAP_t$
Mean	0.935	1.030
Median	0.498	0.503
Std deviation	2.760	2.546
10-percentile	-1.586	-0.924
25-percentile	-0.435	-0.421
75-percentile	1.556	1.785
90-percentile	4.374	4.129
Difference between 90- and 10-percentile	5.960	5.053

5.5 Empirical results: The price information and relationship hypotheses

5.5.1 Measuring a trader's ex ante price information and broker-client relationships

Table 5-2 and Table 5-3 provide evidence that execution costs differ substantially across traders in the money market. Prior literature suggests these differences could be attributable to a trader's *ex ante* price information (Schultz, 2001; and Harris and Piwowar, 2006) or broker-client relationships (Bernhardt et al., 2005). To investigate the source of the discrepancy in execution costs between traders, this section develops two variables: a price information variable and a broker-client relationship variable.

The broker-client relationship variable, *BrokerRel,* measures the strength of the relationship between a trader and their broker. Bernhardt et al. (2005) find that brokers with strong broker-dealer relationships receive greater price improvements. Their key measure of the strength of the relationship is the volume transacted between broker and dealer. Similar to Bernhardt et al. (2005), this chapter uses the notional value of BABs and NCDs transacted between broker and client as a measure of the strength of the relationship. To measure the relationship between broker and client, *BrokerRel* separates traders into four groups based on the strength of the relationship with a broker. Traders are ranked based on their total notional value traded in BABs and NCDs across the entire sample and divided into mutually exclusive quartiles. Group 1 contains traders with the smallest notional value across the sample (least valued clients) and Group 4 contains traders with the largest notional value across the sample (most valued clients).

To proxy for the relationship between dealer and institution, Schultz (2001) examines a subsample of institutions and compares the execution costs of institutions trading with their regular dealer(s) against the execution costs of institutions trading with dealers they rarely use.[106] In contrast, the analysis in this chapter separates individual traders into four groups based on the strength of the relationship with their broker and compares execution costs across the four groups. This methodology refines Schultz (2001) in two significant ways. First, it accounts for the relationship *individual* traders establish with their broker as opposed to aggregating this relationship at an institutional level. This is illustrated in Table 5-4, which compares execution costs incurred by

[106] Schultz (2001) only examines the relationship between institution and dealer for institutions he defines as 'active'. That is, the 20 institutions with the largest dollar volume traded across the period.

individual traders and institutions. Second, the methodology in this chapter encompasses all traders in the sample as opposed to a subset of traders.

Table 5-4

Average execution costs for institutions and individual traders

This table presents average execution costs for trade packages of BABs and NCDs for institutions that have more than one individual trader in the sample. Average execution costs are reported for the institution as a whole and then each trader individually. Execution costs are calculated as the difference between the value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. All execution costs are reported in basis points.

	Average execution costs (bps)							Difference
	Institution	*Trader 1*	*Trader 2*	*Trader 3*	*Trader 4*	*Trader 5*	*Trader 6*	*|Best - Worst|*
1	-0.663	0.487	-0.740	-	-	-	-	1.227
2	-0.244	0.791	-0.279	1.719	-	-	-	1.998
3	-0.426	-0.844	-0.393	-0.379	-	-	-	0.465
4	0.515	0.330	0.886	-	-	-	-	0.556
5	0.084	-0.280	0.509	-	-	-	-	0.789
6	-0.843	-0.435	-2.475	-	-	-	-	2.040
7	-0.121	0.850	-0.201	-	-	-	-	1.051
8	-0.489	-1.088	-0.223	-0.664	-	-	-	0.865
9	-0.490	-0.491	-0.396	-	-	-	-	0.095
10	-0.549	-0.279	-0.571	-	-	-	-	0.292
11	2.562	2.799	2.323	-	-	-	-	0.476
12	1.546	1.552	1.306	-	-	-	-	0.246
13	-0.207	0.007	-2.255	-	-	-	-	2.262
14	0.302	0.126	0.117	0.353	-	-	-	0.236
15	0.846	0.357	2.495	8.389	-	-	-	8.032
16	-0.401	-0.236	-3.498	9.180	-	-	-	9.416
17	2.060	0.659	6.264	-	-	-	-	5.606
18	2.333	-0.514	3.415	2.972	1.466	2.376	2.382	3.929
19	5.418	4.277	8.596	6.317	4.040	4.374	3.420	5.176
20	1.336	0.028	1.051	12.201	-	-	-	12.17
21	-1.655	-0.715	-2.125	-	-	-	-	1.410
22	-0.040	0.643	-0.119	-2.960	0.960	2.381	-	5.342

Table 5-4 reports results from an analysis of trading costs within institutions. Average execution costs are reported for each institution with more than one individual trader participating in the money market. Within each of the 22 institutions in Table 5-4, there is significant variation in execution costs across individual traders. For example, institution 7 incurs average execution costs of -0.121 basis points; however, trader 1's average execution costs are 0.850 basis points and trader 2's average execution costs are -0.201 basis points. If the execution costs of institution 7 were applied to the individual traders, trader 1's execution costs would be overestimated by 0.080 basis points and trader 2's execution costs would be underestimated by 1.051 basis points. This shows that data identifying individual traders as opposed to institutions provide a more refined measure of execution costs, and in turn, the relationship between broker and client.

The market price information variable, *TraderPriceInfo*, captures the price information obtained by a particular trader prior to executing their trade package. Schultz (2001) and Harris and Piwowar (2006) suggest that traders regularly participating in an opaque market possess superior knowledge of market prices. *TraderPriceInfo* proxies for the price information available to trader j prior to executing trade package i on day t, and is measured as the number of trade packages executed by trader j on day $t-1$ in the same maturity group k as trade package i. Traders active in the market prior to executing their trade package obtain an informational advantage over their less active counterparts and are predicted to incur lower execution costs.

To measure a trader's *ex ante* market price information, both Schultz (2001) and Harris and Piwowar (2006) argue that institutions trading frequently in opaque markets are at an informational advantage compared to less active institutions. To account for the price information obtained by an institution through their trading activity, Schultz (2001) creates a dummy variable which categorises 20 institutions by their dollar volume transacted over a 28-month period. The limitation of this measure is that it classifies institutions that transact a large dollar volume in a small number of trades as 'active'. This dissertation suggests that an active institution's price information is more accurately measured by their trading frequency rather than their total dollar volume, and further refines the price information proxy in Schultz (2001) by (i) measuring a trader's price information *ex ante* and hence quantifying information at the point of execution, and (ii) measuring trading activity based solely on the previous day's trading, therefore accounting for the short-lived nature of information in markets.

To provide an initial characterisation of execution costs, Table 5-5 reports average execution costs for each *BrokerRel* group (Panel A) and *TraderPriceInfo* value (Panel B). Consistent with Bernhardt et al. (2005), Panel A of Table 5-5 documents that average execution costs decrease monotonically as the value brokers place on clients increases. The least valued clients in Panel A (*BrokerRel* Group 1) incur average execution costs of 2.021 basis points, while the most valued clients (*BrokerRel* Group 4) incur average execution costs of -0.094 basis points. Table 5-5 shows that a broker's most important clients will, on average, incur execution costs 2.115 basis points lower than other less important clients. This is consistent with the prediction of hypothesis $H_{5,3.}$

The results reported in Panel A of Table 5-5 are not consistent with Schultz (2001), as he finds that relationships between institutions and dealers do not explain differences in institutional execution costs.[107] It is possible that this inconsistency arises due to data differences. Schultz (2001) utilises data at an institutional level, while this study employs data at an individual trader level. Results in Table 5-4 highlight the significant difference in execution costs within institutions, providing evidence that aggregating execution costs at an institutional level could generate noisy estimates.

[107] See Footnote 7, p.689 in Schultz (2001).

Table 5-5

Average execution costs for trade packages as determined by *BrokerRel* and *TraderPriceInfo*

This table presents average execution costs for trade packages of BABs and NCDs. Panel A reports execution costs as determined by strength of the relationship a trader has with their broker (*BrokerRel*). To form the *BrokerRel* groups in Panel A, individual traders are ranked based on the combined notional value of all their trade packages and sorted into four mutually exclusive quartiles. Group 1 contains traders with the smallest total notional value (least valued clients), and Group 4 contains traders with the largest total notional value (most valued clients). Panel B reports execution costs as determined by the trader's *ex ante* price information (*TraderPriceInfo*). In Panel B, a trader's *ex ante* price information is measured as the number of trade packages executed by trader *j* on day *t-1* in the same maturity group *k* as trade package *i*. Execution costs are calculated (i) as the difference between the notional value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and (ii) as the difference between the VWAP of the trade package and the matched VWAP on the day ($VWAP_t$). Execution costs are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. All execution costs are reported in basis points.

	Execution costs (bps)	
	$VWAP_{t-1}$	$VWAP_t$
Panel A: BrokerRel		
1 (Least valued)	2.021	1.937
2	1.076	1.100
3	0.468	0.419
4 (Most valued)	-0.094	-0.054
Panel B: TraderPriceInfo		
0 (Least informed)	0.769	0.679
1	0.265	0.261
2	0.064	0.088
3	-0.224	-0.222
4	-0.292	-0.209
> 5 (Most informed)	-0.331	-0.221

Panel B of Table 5-5 reports that average execution costs decline as a trader's *ex ante* price information increases. The least informed traders (*TraderPriceInfo* = 0) incur average execution costs of 0.760 basis points and the most informed traders (*TraderPriceInfo* > 5) incur average execution costs of -0.331 basis points.[108] This implies that traders with *ex ante* price information in an opaque market incur average execution costs 1.091 basis points lower than traders with no *ex ante* price information. These results are consistent with the hypothesis $H_{5,2}$ and Schultz (2001).

5.5.2 The robustness of trade size, BrokerRel, and TraderPriceInfo

The analysis thus far identifies three variables that are related to average execution costs in opaque markets – trade package size, broker-client relationships, and a trader's *ex ante* price information. Each of these variables demonstrates a strong negative relation with execution costs. To determine the individual explanatory power of each variable, this section separates the effects of trade package size, *BrokerRel*, and *TraderPriceInfo* on execution costs. The methodology implemented to separate these three variables is similar to the informal testing of beta and market capitalisation by Fama and French (1992).

[108] Trade packages with an associated *TraderPriceInfo* value of greater than five are aggregated in Table 5-5 and Table 5-7, as there are a limited number of trade packages with *TraderPriceInfo* greater than five.

Table 5-6 reports average execution costs for trade packages sorted on *BrokerRel* and trade package size groups.[109] The columns in Table 5-6 depict the relation between execution costs and *BrokerRel* after controlling for trade package size, while the rows in Table 5-6 depict the relation between execution costs and trade package size after controlling for broker-client relationships. The columns in Table 5-6 reveal that a strong negative relation between average execution costs and *BrokerRel* remains after controlling for trade package size. Conversely, after controlling for broker-client relationships, there is no longer a discernable pattern in execution costs along the rows in Table 5-6. The negative relation between trade package size and average execution costs reported in Table 5-2 does not appear robust to the presence of the *BrokerRel* variable.

[109] Note that the size groups in Table 5-6 are consistent with the size groups in Table 5-2.

Table 5-6
Average execution costs sorted on *BrokerRel* (down) and trade package size (across)

This table presents average execution costs for trade packages of BABs and NCDs sorted by *BrokerRel* (down) and trade package size (across). *BrokerRel* measures the strength of the relationship between broker and client. To form the *BrokerRel* groups, individual traders are ranked based on the combined notional value of all their trade packages and sorted into four mutually exclusive quartiles. Group 1 contains traders with the smallest total notional value (least valued clients), and Group 4 contains traders with the largest total notional value (most valued clients). The trade package size variable ranks trade packages by their notional value and sorts them into five mutually exclusive size quintiles. Group 1 contains the smallest trade packages and Group 5 contains the largest trade packages. Execution costs are calculated (i) as the difference between the value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and (ii) as the difference between the VWAP of the trade package and the matched VWAP on the day ($VWAP_t$). Execution costs are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. All execution costs are reported in basis points.

	Trade package size (1 = smallest, 5 = largest)									
	Execution costs ($VWAP_{t-1}$, bps)					Execution costs ($VWAP_t$, bps)				
BrokerRel	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
1 (Least valued)	1.639	1.937	4.165	2.814	-	1.614	1.878	3.736	2.477	-
2	1.216	0.482	0.998	1.283	2.613	1.574	0.843	1.023	0.987	1.082
3	0.935	0.347	0.590	0.578	-0.249	0.426	0.581	0.500	0.469	-0.048
4 (Most valued)	-0.304	0.109	0.189	0.020	-0.405	-0.107	0.070	0.149	-0.010	-0.277

Table 5-7

Average execution costs sorted on *TraderPriceInfo* (down) and trade package size (across)

This table presents average execution costs for trade packages of BABs and NCDs sorted by *TraderPriceInfo* (down) and trade package size (across). *TraderPriceInfo* quantifies the *ex ante* price information available to trader *j* prior to executing trade package *i* on day *t*, and is measured as the number of trade packages executed by trader *j* on day *t-1* in the same maturity group *k* as trade package *i*. The trade package size variable ranks trade packages by their notional value and sorts them into five mutually exclusive size quintiles. Group 1 contains the smallest trade packages, and Group 5 contains the largest trade packages. Execution costs are calculated (i) as the difference between the value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and (ii) as the difference between the VWAP of the trade package and the matched VWAP on the day ($VWAP_t$). Execution costs are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. All execution costs are reported in basis points.

	Trade package size (1 = smallest, 5 = largest)									
	Execution costs ($VWAP_{t-1}$, bps)					Execution costs ($VWAP_t$, bps)				
TraderPriceInfo	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
0 (Least informed)	1.528	1.163	0.825	0.796	-0.324	1.211	1.220	0.340	0.649	0.137
1	0.558	0.205	0.599	0.388	-0.374	0.638	0.102	0.783	0.216	-0.336
2	0.766	0.146	0.425	-0.089	-0.401	0.661	0.223	0.392	-0.067	-0.312
3	-0.145	-0.364	-0.193	-0.022	-0.390	-0.250	-0.277	-0.203	-0.006	-0.386
4	-0.303	-0.208	-0.094	-0.579	-0.172	0.141	-0.138	-0.035	-0.485	-0.334
> 5 (Most informed)	-0.233	-0.183	-0.089	-0.693	-0.389	-0.326	-0.023	-0.110	-0.530	-0.314

Table 5-7 documents average execution costs for trade packages sorted on *TraderPriceInfo* and trade package size groups, with the columns and rows interpreted similarly to Table 5-6. After controlling for package size, the negative relation between average execution costs and *TraderPriceInfo* remains. Similarly, after controlling for trader information, the negative relation between average execution costs and trade package size remains; however, the presence of the trader information variable reduces the strength of the relation.

As a final test, Table 5-8 reports average execution costs for trade packages sorted by *TraderPriceInfo* and *BrokerRel*. The negative relation between *TraderPriceInfo* and execution costs remains after controlling for broker-client relationships. Similarly, the negative relation between *BrokerRel* and execution costs remains after controlling for a trader's *ex ante* price information. The co-existence of the price information and relationship hypotheses in Table 5-8 confirms that both are important determinants of execution costs. The analysis thus far is unable to determine the dominant hypothesis, as Table 5-8 shows the importance of both the price information and relationship hypotheses in determining execution costs. Section 5.6 utilises regression analysis to directly test hypothesis $H_{5,4}$, with a specific focus on isolating the dominant effect.

Table 5-8
Average execution costs sorted on *TraderPriceInfo* (down) and *BrokerRel* (across)

This table presents average execution costs for trade packages of BABs and NCDs sorted by trader information (down) and broker-client relationship groups (across). *TraderPriceInfo* quantifies the *ex ante* price information available to trader *j* prior to executing trade package *i* on day *t*, and is measured as the number of trade packages executed by trader *j* on day *t-1* in the same maturity group *k* as trade package *i*. *BrokerRel* measures the strength of the relationship between broker and client. To form the *BrokerRel* groups, individual traders are ranked based on the combined notional value of all their trade packages and sorted into four mutually exclusive quartiles. Group 1 contains traders with the smallest total notional value (least valued clients), and Group 4 contains traders with the largest total notional value (most valued clients). Execution costs are calculated (i) as the difference between the value-weighted average price (VWAP) of the trade package and the matched VWAP from the previous trading day ($VWAP_{t-1}$) and (ii) as the difference between the VWAP of the trade package and the matched VWAP on the day ($VWAP_t$). Execution costs are multiplied by a binary variable that equals 1 for buy packages and -1 for sell packages. All execution costs are reported in basis points.

	BrokerRel (1 = least valued, 4 = most valued)							
	Execution costs ($VWAP_{t-1}$, bps)				Execution costs ($VWAP_t$, bps)			
TraderPriceInfo	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
0 (Least informed)	1.625	1.328	0.759	0.292	1.564	1.227	0.507	0.239
1	1.383	0.714	0.423	0.215	1.584	0.896	0.480	0.126
2	0.796	0.790	0.413	-0.030	1.408	1.082	0.531	-0.018
3	-	-	0.405	-0.222	-	-	0.464	-0.227
4	-	-	0.276	-0.237	-	-	0.368	-0.168
> 5 (Most informed)	-	-	-0.641	-0.259	-	-	-0.526	-0.163

5.6 Empirical results: The determinants of execution costs

To measure the effects of trade package size, a trader's *ex ante* price information, and broker-client relationships on execution costs (*EC)*, the following regression is estimated:

$$\begin{aligned} EC_{it} &= \alpha + \beta \ln(S)_{it} + \chi TraderPriceInfo_{k,t-1} \\ &\quad + \delta \sum_{n=2}^{n=4} BrokerRel_j + \varepsilon_i \end{aligned} , \tag{5-2}$$

where ln*(S)* is the natural logarithm of the notional value of trade package *i* executed on day *t*. *TraderPriceInfo* captures the price information available to trader *j* prior to executing trade package *i* on day *t*, and is measured as the number of trade packages executed by trader *j* on day *t-1* in the same maturity group *k* as trade package *i*. *BrokerRel* is a series of dummy variables that capture the strength of the relationship between a trader and broker. Traders are ranked based on the total notional value of all their trade packages and divided into mutually exclusive quartiles. Group 1 contains traders with the smallest notional value across the sample (least valued clients) and Group 4 contains traders with the largest notional value across the sample (most valued clients). The *BrokerRel* dummy variables are standardised by Group 1.

Regression estimates and *t*-statistics for various forms of Eq. (5-2) are reported in Table 5-9. The first column of Table 5-9 documents coefficient estimates for the regression of execution costs on the logarithm of trade package size.

Consistent with hypothesis $H_{5,1}$, Table 5-2, and prior literature, the coefficient of the trade size variable is negative and statistically significant. The very low adjusted R-square of this model (< 0.4%) implies trade package size contains little explanatory power.

The second column of Table 5-9 reports coefficient estimates from a regression model containing the log of trade package size and *TraderPriceInfo*. As predicted, the coefficient estimate of *TraderPriceInfo* is negative and statistically significant, providing evidence in support of hypothesis $H_{5,2}$. That is, traders with superior *ex ante* information incur lower execution costs.

The full regression model is reported in the third column of Table 5-9. The coefficients of the *BrokerRel* dummy variables are statistically significant and become increasingly negative as the strength of the relationship increases. This confirms hypothesis $H_{5,3}$, which predicts that traders who establish a strong relationship with their broker incur lower execution costs than traders who do not. Specifically, a broker's most valued clients (Group 4) incur average execution costs 1.871 basis points lower than a broker's least valued clients (Group 1). In addition, the trade package size variable is statistically insignificant in the full regression model, directly contradicting hypothesis $H_{5,1}$. The results for the full regression model reported in Table 5-9 are consistent with earlier findings reported in Table 5-6 and Table 5-8. Table 5-8 demonstrates the co-existence of a trader information effect and a broker-client relationship effect, while Table 5-6 shows that after controlling for broker-client relationships, the trade package size effect disappears.[110]

Finally, a comparison of the magnitude of the coefficients of *TraderPriceInfo* and *BrokerRel* shows that if traders establish a strong relationship with their broker they can achieve a greater reduction in execution costs than if they are active in the market and possess *ex ante* price information. In the full regression model, a trader with *ex ante* price information incurs average execution costs 0.081 basis points lower than a trader with no information, while a trader with a strong broker relationship incurs average execution costs 1.871 basis points lower than a trader with a weak broker relationship. These results do not support hypothesis $H_{5,4}$, which predicts that traders with *ex ante* price information achieve a greater reduction in execution costs than traders who establish a strong relationship with their broker.

[110] It is necessary at this point to discuss the interaction of the trade package size, *TraderPriceInfo*, and *BrokerRel* variables. These interactions somewhat affect regressions in Table 5-9, as evidenced by the change in magnitude of the average slope coefficients when introducing the broker-client relationship dummy variables to the model. The Spearman's Rank correlation coefficient is 0.063 for package size and *TraderPriceInfo*, and 0.240 for package size and *BrokerRel*. Stuart's Tau-c for *TraderPriceInfo* and *BrokerRel* is 0.313. These numbers demonstrate a weak positive correlation between package size and *BrokerRel* and a weak positive association between *TraderPriceInfo* and *BrokerRel*.

Table 5-9
The determinants of execution costs

This table presents regression results from the following model:

$$EC_{it} = \alpha + \beta \ln(S)_{it} + \chi TraderPriceInfo_{k,t-1} + \delta \sum_{n=2}^{n=4} BrokerRel_j + \varepsilon_i$$

Where EC_{it} is the execution cost incurred by trade package *i* executed on day *t*. Execution costs are measured as the difference between the value-weighted average price (VWAP) of the trade package and one of two benchmarks; the VWAP on the previous day ($VWAP_{t-1}$) and the VWAP on the day ($VWAP_t$). $\ln(S_{ij})$ is the natural logarithm of the trade package notional value. *TraderPriceInfo* quantifies the *ex ante* price information available to trader *j* prior to executing trade package *i* on day *t*, and is measured as the number of trade packages executed by trader *j* on day *t-1* in the same maturity group *k* as trade package *i*. *BrokerRel* is a series of dummy variables that measure the strength of the relationship between broker and client. To form the *BrokerRel* groups, individual traders are ranked based on the combined notional value of all their trade packages and sorted into four mutually exclusive quartiles. Group 1 contains traders with the smallest total notional value (least valued clients), and Group 4 contains traders with the largest total notional value (most valued clients). The series of *BrokerRel* dummy variables are standardised by Group 1. There are 108 traders used in the analysis. Buys and sells are reported together. *t*-statistics are adjusted for heteroscedasticity and autocorrelation, and the Durbin-Watson statistic, the F-statistic, and the adjusted R-square is reported for each model.

	Dependent variable: Execution costs (bps)					
	$VWAP_{t-1}$			$VWAP_t$		
	1	*2*	*3*	*1*	*2*	*3*
Intercept	3.065**	3.158**	2.896**	2.950**	3.033**	2.788**
Log notional value	-0.164**	-0.151**	-0.052	-0.156**	-0.145**	-0.051
TraderPriceInfo		-0.173**	-0.081*		-0.154**	-0.069**
BrokerRel						
DV 2			-0.880*			-0.776*
DV 3			-1.442**			-1.415**
DV 4 (Most valued)			-1.871**			-1.773**
Adjusted R-Square	0.0039	0.0122	0.0273	0.0052	0.0149	0.0351
DW	1.9501	1.9669	1.9986	1.9713	1.9910	2.0316
F-Statistic	20.07	31.48	28.71	26.62	38.24	36.83

* Significantly different from zero at the 5% level
** Significantly different from zero at the 1 % level

5.7 Summary

Two competing hypotheses in the literature attempt to explain the observed negative relation between execution costs and trade size in opaque markets – the price information hypothesis and the relationship hypothesis. Chapter 5 focuses specifically on these two hypotheses and their relative effects on execution costs in the money market.

This chapter provides evidence that both the price information hypothesis and the relationship hypothesis explain trader execution costs in an opaque market; however, the relationship hypothesis is the dominant effect. That is, traders who establish a strong relationship with their broker achieve a greater reduction in execution costs. Chapter 5 shows that after controlling for the effects of these two hypotheses on execution costs, trade size has little explanatory power.

Chapter 6

Liquidity and transaction costs in the European carbon futures market

6.1 Introduction

Section 2.3 of this dissertation highlights the dearth of literature examining carbon market microstructure. In particular, there is no study to date that analyses liquidity and transaction costs in the world's largest and most liquid carbon market: the European Union Emissions Trading Scheme (EU ETS). In 2007, carbon emissions worth approximately 50.39 billion US dollars traded via the EU ETS. Chapter 6 of this dissertation reconciles this deficiency in the literature by conducting the first intraday analysis of liquidity and transaction costs in the European carbon futures market.

Spot trading in the EU ETS officially commenced in 2005. Thus, as is the case with new and emerging markets, the first hypothesis ($H_{6,1}$) predicts that trading activity will improve as the carbon market matures. The second hypothesis ($H_{6,2}$) predicts that, in line with the expected improvement in trading activity, transaction costs will decline. More specifically, the hypothesis predicts that over time as the carbon market matures the bid-ask spread will decline and market depth will increase. New and emerging markets are also associated with increased levels of price volatility (Domowitz et al., 2001). Thus, the third hypothesis ($H_{6,3}$) predicts that trading in European carbon futures is associated with high levels of price volatility. The final hypothesis ($H_{6,4}$) predicts that due to several unique features of carbon futures, large trades in the European carbon futures market are likely to contain information.

The remainder of this chapter is organised as follows. Section 6.2 describes the data and subsequent sample, and provides institutional detail. Sections 6.3 and 6.4 describe the research design and present empirical results. Section 6.5 contains a summary of the chapter.

6.2 Data, sample, and institutional detail

6.2.1 Data and sample

The data used in this study are sourced from the Intercontinental Exchange (ICE) and Reuters and describe trading in ECX CFI futures.[111] The ICE data describe daily on-market and off-market volume from April 22, 2005 to June 25, 2008. The Reuters data describe all on-market transactions from October 10, 2005 to June 16, 2008.[112] Each trade record in the Reuters data contains fields which document the date, time, price, volume, best bid price and volume, and best ask price and volume associated with each trade. Bid and ask quotes are the prevailing best quotes immediately prior to the trade.

[111] ICE data are used only to determine the proportion of trades executed on-market and the increase in total trading volume since inception. The remainder of the analysis in this chapter utilises Reuters data.
[112] ECX CFI futures commenced trading on April 22, 2005; however, Reuters intraday data are only available from October 10, 2005.

Contracts of all maturities are included in the sample and trades reported in US dollars are included in the volume analysis but excluded from the price volatility and transaction cost analysis.[113]

Table 6-1 describes the Reuters data set. There are a total of 116,559 on-market trades available for analysis. The average on-market trade size is 8.58 contracts, with minimum and maximum on-market trade sizes of one and 600 contracts respectively. The distribution of trade sizes across the sample suggests that the majority of on-market trades are small, with 50 per cent of trades in the sample consisting of five contracts or less.

Trades in the December 2008 contract account for approximately 70 per cent of all trades in the sample. The sample contains 82,646 on-market trades in December 2008 futures, and each trade has an average volume of 7.4 contracts. Section 6.3 and Section 6.4 examine ECX CFI December 2008 futures in detail.

[113] Trades in US dollars represent less than one per cent of the sample.

Table 6-1
Descriptive statistics

This table reports descriptive statistics for all ECX CFI futures contracts in the sample. Statistics are reported separately for each December expiry month contract, and Non-December expiry months are grouped together. *Trade Volume* is the total number of contracts per trade, where each contract represents 1,000 tonnes of carbon dioxide. The table reports the mean, standard deviation, and distribution of trade volume for each contract and the entire sample. Note that the sample contains on-market trades only.

	Trade Volume		Percentiles: Trade Volume							
Contract	*Mean*	*Std Dev*	*Min.*	*10%*	*25%*	*50%*	*75%*	*90%*	*Max.*	*N*
December 2005	13.08	20.70	1	5	9	10	10	20	375	1,327
December 2006	11.74	15.15	1	4	5	10	10	20	600	16,822
December 2007	12.97	17.46	1	2	5	10	10	25	300	8,280
December 2008	7.400	9.015	1	1	1	5	10	15	500	82,646
December 2009	8.063	10.37	1	1	2	5	10	17	129	3,705
December 2010	7.850	10.57	1	1	1	5	10	20	194	1,497
December 2011	10.36	14.27	1	1	5	5	10	25	175	450
December 2012	14.02	19.92	1	1	5	10	15	40	200	654
December 2013	10.00	0.000	10	10	10	10	10	10	10	4
Non-December months	9.255	16.72	1	1	2	5	10	20	200	1,174
Total sample	8.580	11.49	1	1	2	5	10	20	600	116,559

6.2.2 Institutional detail

The European Climate Exchange (ECX) offers futures and options contracts on EUAs and futures contracts on CERs.[114] ECX CFI futures are the most liquid ECX contract and are the focus of this study. ECX CFI futures are traded on the Intercontinental Exchange (ICE), formerly the International Petroleum Exchange, alongside several of Europe's largest oil and energy contracts. The ICE platform consists of an electronic limit order book, as well as facilities for Block Trading and Exchange for Physical (EFP). Trading hours on ICE Futures for the ECX CFI contract are currently 07.00 – 17.00 UK local time, consistent with other ICE energy contracts.

The underlying asset of an ECX CFI futures contract is 1,000 EUAs (1,000 tonnes of carbon dioxide), and the contract is physically settled. Prices are quoted in euro cents per metric tonne, and the current minimum tick is one euro cent. The minimum tick decreased from five euro cents to one euro cent on 27 March, 2007. Both monthly and yearly contracts are available. Table 6-2 contains the contract specifications for ECX CFI futures.

[114] CER futures commenced trading in March 2008.

Table 6-2
Contract Specifications for ECX CFI futures
This table reports the contract specifications for ECX CFI futures.

Contract	ECX CFI Futures
Unit of trading	1 lot = 1,000 CO_2 EU Allowances (EUAs) 1 EUA = entitlement to emit 1 tonne of CO_2 or equivalent
Minimum trade size	1 lot
Quotation	Euro (€) and euro cent (c) per metric tonne
Tick size	€0.01 per tonne (€10 per lot)*
Max. price fluctuation	No limit
Contract months	Monthly – September 2006 to March 2008 (Phase I) Yearly – December expiries 2008 to 2012 (Phase II)
Expiry day	Last Monday of contract month
Trading hours	07.00 – 17.00 UK local time
Settlement price	Trade-weighted average during the daily closing period (17.00-17.15) with Quoted Settlement Prices if liquidity is low.
Settlement and delivery	Physically settled. Transfer of EUAs in a national registry three days after last trading day (LTD+3 delivery)
Margin	All open contracts marked-to-market daily

Source: www.theice.com
*The tick size decreased from €0.05 to €0.01 on 27 March, 2007.

6.3 Research design and empirical results: Trading activity and price volatility

6.3.1 Trading volume: All expiry months

As a preliminary analysis of the level of trading activity in ECX CFI futures, Table 6-3 reports the total on-market volume traded in each contract.[115] To examine changes in trading activity over time, total volume is reported on a quarterly basis. Table 6-3 documents a dramatic improvement in overall on-market trading activity. This is particularly noticeable in the March and June Quarters of 2008, where a total of 150,063 and 155,781 contracts were traded,

[115] An analysis of ICE data shows that the average proportion of daily on-market volume to daily off-market volume is 39.04 per cent.

respectively.[116] The improvement in on-market trading activity reported in Table 6-3 is supported by ICE data which document a 102 per cent increase in the total number of contracts traded both on- and off-market since inception. These results are consistent with hypothesis $H_{6,1}$, as they report a marked increase in liquidity as the carbon market matures.

Table 6-3 also reports on-market trading activity by contract expiry month, revealing several patterns in trading volume. First, trading is concentrated in December expiry month contracts. Trading volume in non-December month contracts represents between zero and 7.43 per cent of total quarterly trading volume. This concentration of liquidity in December contracts coincides with the annual audit of company and Member State emissions. Second, trading volume in December 2007 contracts deteriorates significantly during 2007. As Phase I EUAs are not fungible with Phase II EUAs, December 2007 futures traded at less than one euro for most of 2007. This most likely exacerbated the natural shift from trading Phase I to Phase II contracts.[117] Third, December 2008 futures are by far the most liquid ECX CFI futures contract. Contracts expiring in December 2008 traded heavily from the December Quarter 2006, even though Phase II EUAs did not begin trading on the spot market until March 2008. This strongly suggests that price discovery occurs in the futures market. Finally, even though Phase III emissions caps are unknown, there are four on-market trades executed in December 2013 futures on June 5, 2008.

[116] Note that the data for the June Quarter 2008 do not encompass trades after June 16, 2008.
[117] The European Commission rectified this problem by permitting banking of unused Phase II EUAs for use in Phase III. This should ensure a relatively smooth transition at the end of Phase II.

Table 6-3
On-market trading volume: All contracts

This table reports the breakdown of on-market trading volume across contracts on a quarterly basis. On-market trading volume is the total number of contracts traded per quarter. One contract represents 1,000 tonnes of carbon dioxide. The percentage of total quarterly on-market volume is reported in parentheses.

	Contract expiry month										
	Dec 2005	Dec 2006	Dec 2007	Dec 2008	Dec 2009	Dec 2010	Dec 2011	Dec 2012	Dec 2013	Non-December	All Contracts
Dec Q 2005	17,354	14,998	3,391	280	-	-	-	-	-	605	36,628
	(47.38%)	(40.95%)	(9.26%)	(0.76%)	-	-	-	-	-	(1.65%)	(100%)
Mar Q 2006	-	52,662	10,253	2,800	45	-	35	20	-	5,285	71,100
	-	(74.07%)	(14.42%)	(3.94%)	(0.06%)	-	(0.05%)	(0.03%)	-	(7.43%)	(100%)
Jun Q 2006	-	77,199	15,371	15,338	226	-	-	-	-	280	108,414
	-	(71.21%)	(14.18%)	(14.15%)	(0.21%)	-	-	-	-	(0.26%)	(100%)
Sep Q 2006	-	34,643	11,666	15,958	100	-	-	-	-	180	62,547
	-	(55.39%)	(18.65%)	(25.51%)	(0.16%)	-	-	-	-	(0.29%)	(100%)
Dec Q 2006	-	17,923	17,845	20,424	15	20	-	-	-	-	56,227
	-	(31.88%)	(31.74%)	(36.32%)	(0.03%)	(0.04%)	-	-	-	-	(100%)
Mar Q 2007	-	-	23,400	44,341	348	-	-	1	-	370	68,460
	-	-	(34.18%)	(64.77%)	(0.51%)	-	-	(0.00%)	-	(0.54%)	(100%)
Jun Q 2007	-	-	15,348	71,398	2,466	126	323	143	-	-	89,804
	-	-	(17.09%)	(79.50%)	(2.75%)	(0.14%)	(0.36%)	(0.16%)	-	-	(100%)
Sep Q 2007	-	-	2,401	98,188	6,572	1,733	735	2,742	-	-	112,371
	-	-	(2.14%)	(87.38%)	(5.85%)	(1.54%)	(0.65%)	(2.44%)	-	-	(100%)
Dec Q 2007	-	-	7,687	71,970	4,458	1,576	689	2271	-	2	88,653
	-	-	(8.67%)	(81.18%)	(5.03%)	(1.78%)	(0.78%)	(2.56%)	-	(0.00%)	(100%)
Mar Q 2008	-	-	-	132,020	8,049	3,693	1,613	2,538	-	2,150	150,063
	-	-	-	(87.98%)	(5.36%)	(2.46%)	(1.07%)	(1.69%)	-	(1.43%)	(100%)
Jun Q 2008	-	-	-	138,825	7,596	4,604	1,267	1,455	40	1,994	155,781
	-	-	-	(89.12%)	(4.88%)	(2.96%)	(0.81%)	(0.93%)	(0.03%)	(1.28%)	(100%)

The descriptive statistics presented in Table 6-1 and results presented in Table 6-3 document limited on-market trading activity outside the December 2008 expiry month. Thus, the remainder of this chapter focuses on December 2008 futures.

6.3.2 Trading activity and price volatility: December 2008 futures

A high level of trading activity is indicative of a well-functioning and liquid futures market. To examine any improvements in trading activity over time, results are presented separately for each quarter. The trading activity of December 2008 ECX CFI futures is measured in three ways – daily volume, daily trade frequency, and trade size. Daily volume is the number of contracts traded per day, daily trade frequency is the number of trades per day, and trade size is the number of futures contracts per trade. If the December 2008 contract does not trade on a designated trading day in the quarter, that day is assigned a value of zero in calculating both the average daily volume and average daily trade frequency for that quarter. This allows quarterly averages to reflect trading across the entire quarter.

Transaction costs are expected to increase in times of high price volatility. This chapter uses two measures of price volatility – the daily price range measured in ticks and the standard deviation of daily returns. The daily price range is the difference between the daily high price and daily low price scaled by the minimum tick, while daily returns are calculated using Reuters opening and closing prices. The minimum tick is held constant at five euro cents to provide a consistent measure across the sample period.[118] Table 6-3 reports trading activity and price volatility for the December 2008 futures contract on a quarterly basis.

Consistent with Table 6-3 and hypothesis $H_{6,1}$, Table 6-4 documents a substantial improvement in trading activity in line with the increasing maturity of the carbon market. The average daily trading volume increases from 4.667 contracts per day in the December Quarter 2005 to 2,570.8 contracts per day in the June Quarter 2008, while the mean daily trading frequency increases from 0.25 trades per day in the December Quarter 2005 to 398.7 trades per day in the June Quarter 2008. The average trade size declines from 17.29 contracts in the December Quarter 2005 to 6.827 contracts in the June Quarter 2008.

[118] On March 27, 2007 the minimum tick decreased from 0.05 Euro to 0.01 Euro.

Table 6-4
Trading activity and price volatility: December 2008 futures

This table reports quarterly trading activity and price volatility for ECX CFI futures expiring in December 2008. *Daily volume* is the daily number of contracts traded on-market and *daily frequency* is the daily number of on-market trades. Both daily volume and daily frequency are assigned values of zero when the contract did not trade on a designated trading day in the quarter. *Trade size* is the number of contracts per trade. *Daily volatility* is the difference between the daily high price and daily low price scaled by the minimum tick and s*td dev of daily return* is the standard deviation of daily returns, where daily returns are measured using Reuters opening and closing prices. The final two columns report the actual minimum tick and the minimum tick used to scale the daily volatility variable. All values reported are mean values calculated separately for each quarter.

	Mean trading activity			Mean price volatility		Minimum tick	
	Daily volume *(No. contracts)*	Daily frequency *(No. trades)*	Trade size *(Lots)*	Daily volatility *(Ticks)*	Std dev of daily return *(Per cent)*	Actual min tick *(Euro)*	Min tick used *(Euro)*
Dec Q 2005	4.667	0.250	17.29	0.000	0.000	0.05	0.05
Mar Q 2006	43.08	2.600	16.79	5.194	0.009	0.05	0.05
Jun Q 2006	239.7	14.34	15.90	26.75	0.077	0.05	0.05
Sep Q 2006	245.5	13.86	15.60	6.571	0.016	0.05	0.05
Dec Q 2006	319.1	34.56	9.429	13.56	0.029	0.05	0.05
Mar Q 2007	692.8	71.91	9.328	14.08	0.035	0.05	0.05
Jun Q 2007	1,116	137.4	7.989	23.50	0.044	0.01	0.05
Sep Q 2007	1,511	171.3	8.725	14.42	0.026	0.01	0.05
Dec Q 2007	1,107	140.0	7.940	10.83	0.017	0.01	0.05
Mar Q 2008	2,096	369.3	5.802	15.68	0.027	0.01	0.05
Jun Q 2008	2,571	398.8	6.827	12.47	0.018	0.01	0.05

Consistent with $H_{6,3}$, daily price volatility reported in Table 6-4 is relatively high when compared to the contract's minimum tick. Both measures of price volatility indicate that volatility is highest in the June Quarter 2006. During this quarter, the mean daily price volatility is 26.750 ticks, and the mean standard deviation of daily returns is 0.077 per cent.

The extreme price volatility experienced during the June Quarter 2006 is a direct consequence of several Member States leaking their 2005 emissions data to the market. The European Commission were to release 2005 emissions data from all Member States in mid-May 2006; however, several Member States unofficially revealed they were net long EUAs between April 24 and April 28 (implying an oversupply of EUAs in the market).[119] The high level of information asymmetry and subsequent price volatility associated with these unofficial announcements continued until the European Commission released 2005 emissions data on May 15, 2006 and cast doubt on the strength of Phase II caps. The price volatility experienced during the June Quarter 2006 demonstrates the adverse impact of information asymmetry on the carbon futures market and immature markets in general.

[119] This followed a record high ECX CFI futures price on April 19.

6.4 Research design and empirical results: Transaction costs

Prior to examining transaction costs, trades are classified as buyer- or seller-initiated using a quote-based rule. Trades executed at the best prevailing ask price are classified as buyer-initiated and trades executed at the best prevailing bid price are classified as seller-initiated. The implementation of a quote-based rule classifies over 99 per cent of trades in the sample. Trades that remain unclassified are excluded from this part of the analysis.

6.4.1 Bid-ask spreads, effective spreads, and depth: December 2008 futures

The bid-ask spread provides a direct measure of the round-trip cost of a transaction. This chapter reports the quoted bid-ask spread immediately prior to each trade in both euro cents and ticks. The bid-ask spread in ticks is the quoted spread scaled by the minimum tick. Similar to the analysis of price volatility, the minimum tick is held constant at five euro cents to provide a consistent measure across the sample period. As a preliminary assessment of the implicit cost of trading, this section also reports effective spreads. The effective spread is measured in ticks and is defined as

$$Effective\ Spread_{i,t} = \left[(VWAP\ Price_i - Midpoint_t)/MinTick\right] * D_i, \quad (6\text{-}1)$$

where $VWAP\ Price_i$ is the volume-weighted average price of trade i, $Midpoint_t$ is the prevailing quote midpoint at the time of the trade, $MinTick$ is the minimum price increment and D_i is 1 for buys and -1 for sells. The minimum tick is held constant at five euro cents.

In addition to the bid-ask spread and the effective spread, this section also examines the number of contracts available at the best bid and best ask prices. Traders require sufficient depth at the best bid and ask to accommodate their trades and to minimise market impact costs. Table 6-5 reports bid-ask spreads, effective spreads, and quoted depth at the best bid and best ask for the December 2008 contract.

Excluding the June Quarter 2006, the quoted bid-ask spread decreases monotonically over time. The quoted bid-ask spread decreases from 55 euro cents in the December Quarter 2005 to 4.3 euro cents in the June Quarter 2008; a decline of 92.1 per cent. The documented decline in the bid-ask spread as the carbon market matures provides support for the first prediction in hypothesis $H_{6,2}$. A similar pattern occurs for the effective spread. When holding the minimum tick constant at five euro cents, the effective spread declines from 5.5 ticks in the December Quarter 2005 to 0.4 ticks in the June Quarter 2008.[120]

Consistent with information-based models, the bid-ask spread widens considerably during the June Quarter 2006.[121] This provides evidence that uncertainty surrounding the supply of Phase I EUAs also cast doubt over emissions caps for Phase II. The widening of the bid-ask spread during this period reflects the substantial information asymmetry present in the market

[120] If scaled by the actual June Quarter 2008 minimum tick of 0.01 Euro, the effective spread for the June Quarter 2008 is 2.19 ticks.
[121] See Glosten and Milgrom (1985) and Easley and O'Hara (1987).

and suggests that it is necessary for carbon market regulators to implement measures to reduce information asymmetry, therefore allowing the market to function efficiently.

Table 6-5 also reports the mean depth at the best prevailing ask quote and the best prevailing bid quote for each quarter in the sample. Depth exhibits minimal variation over time, with little difference between the mean depth at the best ask quote and the mean depth at the best bid quote. The absence of an improvement in market depth over time directly contradicts the second prediction in hypothesis $H_{6,2}$. Further, there is almost no change in available depth between the March and June Quarters of 2007 even though the minimum tick decreased from five euro cents to Euro on March 27, 2007.[122]

[122] Goldstein and Kavajecz (2000) document a 48 per cent decline in limit order book depth at the best quotes when the New York Stock Exchange reduced their minimum tick from one eighth of a dollar to one sixteenth of a dollar.

Table 6-5
Bid-ask spreads, effective spreads, and depth: December 2008 futures

This table reports bid-ask spreads, effective spreads, and depth at the best bid and ask quotes for ECX CFI futures expiring in December 2008. The *quoted bid-ask spread* is the difference between the best bid and best ask quotes immediately prior to each trade and is reported in both euros and ticks. The *effective spread* is measured as the difference between the prevailing midpoint and the volume-weighted average price of the trade and is also scaled by the minimum tick. *Depth at the best ask* and *depth at the best bid* report the number of contracts available at the best ask and best bid immediately prior to each trade. The final two columns report the actual minimum tick and the minimum tick used to scale the bid-ask spread and effective spread. All values reported are mean values calculated separately for each quarter.

	Mean spreads			Mean depth		Minimum tick	
	Quoted bid-ask spread *(Euro)*	Quoted bid-ask spread *(Ticks)*	Effective Spread *(Ticks)*	Depth at the best ask *(Lots)*	Depth at the best bid *(Lots)*	Actual min tick *(Euro)*	Min tick used *(Euro)*
Dec Q 2005	0.550	11.00	5.500	10.00	14.33	0.05	0.05
Mar Q 2006	0.390	7.798	3.899	11.69	11.29	0.05	0.05
Jun Q 2006	0.652	13.04	6.530	15.67	10.66	0.05	0.05
Sep Q 2006	0.197	3.937	1.967	9.649	10.24	0.05	0.05
Dec Q 2006	0.129	2.578	1.288	10.90	12.39	0.05	0.05
Mar Q 2007	0.099	1.970	0.985	12.49	11.59	0.05	0.05
Jun Q 2007	0.083	1.654	0.827	10.92	11.91	0.01	0.05
Sep Q 2007	0.064	1.277	0.638	11.59	12.02	0.01	0.05
Dec Q 2007	0.057	1.135	0.567	10.40	10.05	0.01	0.05
Mar Q 2008	0.050	0.993	0.496	8.270	8.224	0.01	0.05
Jun Q 2008	0.043	0.870	0.438	8.198	7.525	0.01	0.05

6.4.2 Price behaviour surrounding trades in December 2008 futures

To provide an initial characterisation of the price behaviour surrounding trades of different sizes, individual trades are ranked by their total volume and divided into three size groups. Group one (<5 contracts) contains the smallest 60 per cent of trades, Group two (5-15 contracts) contains the next 30 per cent of trades, and Group three (>15 contracts) contains the largest 10 per cent of trades. Similar to Kurov (2005), price behaviour is analysed by calculating average trade-by-trade returns for 10 trades before and 30 trades after each transaction. Returns are calculated using prevailing quote midpoints to mitigate the effects of bid-ask bounce.[123]

Figure 6-1 plots the cumulative average returns (CARs) surrounding trades in December 2008 ECX CFI futures. Across all trade size groups, Figure 6-1 documents an upward return drift prior to buy trades and a downward return drift prior to sell trades of up to 10 basis points. Figure 6-1 also documents a post-trade price adjustment following all trades in ECX CFI futures. That is, quotes are revised upward following buy trades and downward following sell trades. The magnitude of the post-trade price adjustment increases with trade size. CARs at the end of the measurement window for buy (sell) trades in Group 1 are 13.98 (-14.19) basis points, 24.48 (-21.65) basis points in Group 2, and 38.69 (-27.31) basis points in Group 3. All post-trade CARs are statistically significant at the one per cent level.

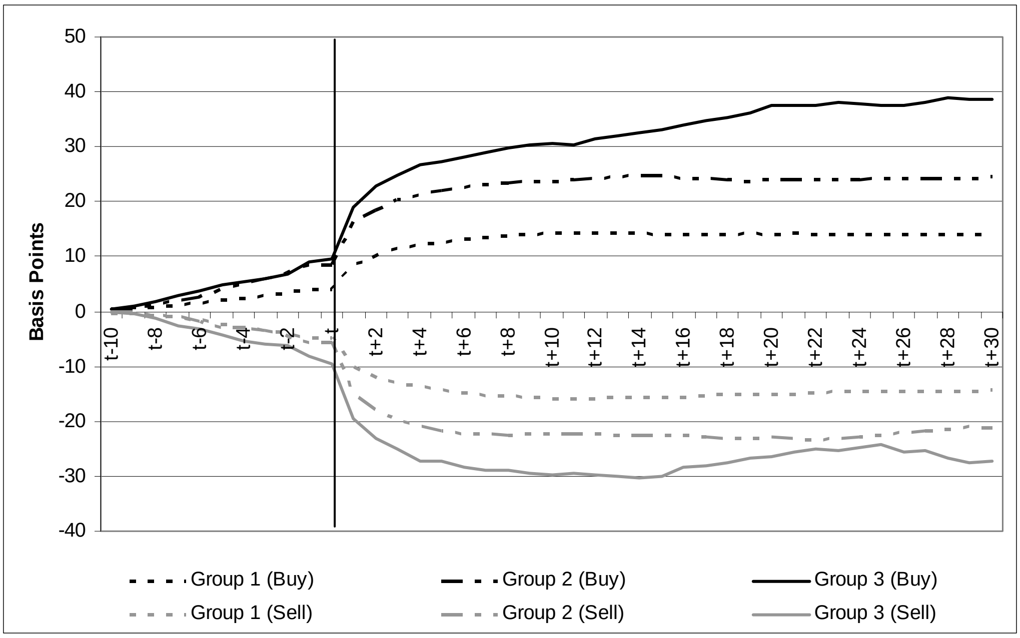
[123] Numerous studies recognise a potential bid-ask bias when using returns calculated with transaction prices, including Vijh (1988), Foerster, Keim, and Porter (1990), Lease, Masulis, and Page (1991), Bhardwaj and Brooks (1992), Gosnell, Keown, and Pinkerton (1996), Rhee and Wang (1997) and Frino, Jarnecic, Johnstone, and Lepone (2005).

To determine the economic significance of the CARs, it is necessary to compare their magnitude to the average bid-ask spread across the sample: 32.28 basis points. The total price adjustment surrounding trades in Group 1 represents no more than half the bid-ask spread, while the total price adjustment surrounding trades in Group 2 and Group 3 is more than half the bid-ask spread (and is greater than the bid-ask spread for the largest buys). This suggests that there is a permanent price effect associated with trades in Group 2 and Group 3. That is, these trades reveal some degree of information to the market, supporting the prediction of hypothesis $H_{6,4}$.

Figure 6-1

Cumulative average returns surrounding small, medium, and large trades

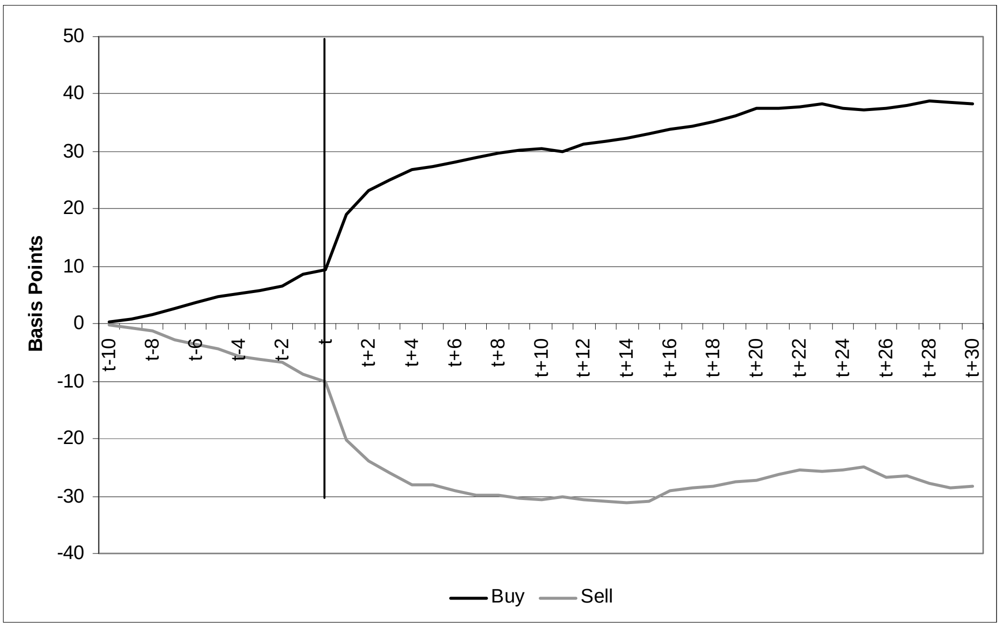
This figure documents cumulative average returns (CARs) surrounding transactions in three trade size groups. Group 1 contains the smallest 60 per cent of trades (<5 contracts), Group 2 contains the next 30 per cent of trades (6-15 contracts), and Group 3 contains the largest 10 per cent of trades (>15 contracts). Average returns are calculated using quotation midpoints and cumulated from 10 trades before to 30 trades after the transaction. Returns are reported separately for buyer- and seller-initiated trades.



To further examine price behaviour surrounding the largest trades, Figure 6-2 plots CARs for the largest five per cent of trades (>20 contracts). Similar to Figure 6-1, Figure 6-2 documents a pre-trade return drift of approximately 10 basis points and a total price adjustment of 38.34 basis points for buys and -28.21 basis points for sells. The magnitude of the CARs in Figure 6-2 exceeds half the bid-ask spread, suggesting there is a permanent price effect associated with both buys and sells in the largest five per cent of trades. Again, this is consistent with hypothesis $H_{6,4}$.

Figure 6-2
Cumulative average returns surrounding the largest five per cent of trades

This figure documents cumulative average returns (CARs) surrounding the largest five per cent of trades (>20 contracts). Average returns are calculated using quotation midpoints and cumulated from 10 trades before to 30 trades after the transaction. Returns are reported separately for buyer- and seller-initiated trades.



6.5 Summary

There is a dearth of literature examining carbon markets from a financial markets perspective. This is highlighted in the literature review in Section 2.3. In particular, no prior literature empirically examines the microstructure of the European carbon market. This chapter conducts the first empirical analysis of liquidity and transaction costs in the European carbon futures market.

Results in Chapter 6 show a dramatic improvement in liquidity and subsequent reduction in transaction costs since the inception of carbon futures trading, in line with the evolution of the carbon market. Additionally, the carbon futures market is relatively volatile, and results provide evidence of a permanent price effect following medium and large trades. On-market liquidity gravitates to December expiry month contracts, coinciding with annual emissions audit requirements. Results also document a widening of the bid-ask spread in response to several Member States leaking 2005 emissions data to the market.

Chapter 7

Conclusions

This dissertation examines the implicit cost of trading in securities markets, with a specific focus on price impact costs. Price impact costs are examined across a range of markets including several futures markets (stock index, interest rate, carbon emissions) and the money market.

The literature review in Chapter 2 highlights several important topics that are underrepresented in the literature. First, despite the importance of futures markets and their substantial liquidity, literature concerning price impact in futures markets is limited. Only three prior studies examine this topic in detail. Second, no prior studies examine the cost of transacting in carbon futures markets. The literature review in Chapter 2 also highlights two inconsistencies in the literature. First, there is conflicting evidence regarding price behaviour following transactions in futures markets. Berkman et al. (2005) and Kurov (2005) document a permanent price effect associated with transactions in futures markets, while Frino and Oetomo (2005) do not. Second, there is inconsistent evidence concerning the origin of the negative relation between execution costs and trade size documented in opaque markets. Schultz (2001) and Harris and Piwowar (2006) attribute the negative relation between execution costs and trade size to the informational advantage obtained by active traders in an opaque market, while Bernhardt et al. (2005) attribute it to the strength of the relationship between a broker and their dealer.

Chapter 3 of this dissertation extends Berkman et al. (2005) and produces broad international evidence of the price impact incurred by block trades in futures markets. The chapter examines 14 stock index futures contracts from 11 different exchanges, and provides evidence of statistically significant price impact associated with block trades in all contracts. Consistent with the analysis of large trades in Berkman et al. (2005), block trades in the majority of contracts examined in Chapter 3 incur a statistically significant temporary price effect. This suggests traders executing large transactions in futures pay a liquidity premium. In contrast with the analysis of large trades in Berkman et al. (2005), the analysis in this chapter provides evidence that block trades in futures markets contain information. This suggests the findings reported for large trades in Berkman et al. (2005) are not applicable to all futures contracts in all markets. Consistent with futures market literature, block buys and sells in the majority of contracts have symmetrical permanent price effects.

Chapter 3 provides a preliminary analysis of price impact and its components in a selection of stock index futures. Many potential avenues for future research arise from results presented in the chapter. For example, an investigation of the determinants of price impact could formally highlight why block trades in some contracts contain information and others do not. The differing information content of buys and sells for several futures contracts also warrants future research, as thus far no explanation for this difference exists.

Chapter 4 of this dissertation aims to resolve an inconsistency in the microstructure literature and examine information effects associated with institutional transactions in futures markets. Previous studies employing intraday benchmarks report that, overall, individual trades have a significant permanent effect on prices in futures markets. Chapter 4 argues that when traders split larger orders into a sequence of smaller trades, intraday benchmarks generate a bias when used to measure the permanent price effect as they do not provide ample time for price pressure to dissipate. Results show that the permanent price effect reported in individual trades is no longer statistically significant once trade package benchmarks are applied to all individual trades belonging to that package. After controlling for the hypothesised bias in the permanent price effect for individual trades, there is little evidence that transactions in futures markets convey information. This re-examination of individual trades reinforces the importance of benchmark selection and robustness testing in price impact studies. In view of the evidence presented in Chapter 4, it is concluded that transactions in futures markets are on average executed by uninformed liquidity traders.

Chapter 5 of this dissertation endeavours to resolve an inconsistency in the strand of literature that concerns execution costs in opaque markets. Empirical studies of execution costs in opaque markets report that execution costs decline as trade size increases. Prior literature attributes this effect to two competing hypotheses – the price information hypothesis and the relationship hypothesis. Consistent with bond market studies, results presented in Chapter 5 show that execution costs in the money market decline as trade size increases, and there is significant variation in execution costs across individual traders. Chapter 5 provides evidence that the price information and relationship hypotheses coexist in an opaque market. That is, both a trader's *ex ante* price information and the strength of their relationship with their broker are statistically significant determinants of execution costs. However, traders in opaque markets achieve a greater reduction in execution costs by establishing a relationship with their broker. After controlling for a trader's *ex ante* price information and the relationship between broker and client, trade size contains little explanatory power.

The respective roles of a trader's *ex ante* price information and broker-client relationships in opaque markets have important implications for public policy, as they indicate there is a need to improve price transparency in these markets. This is the responsibility of market regulators. Any additional price information made available to traders will help minimise the significant execution costs incurred by irregular traders and those without established broker relationships.

Finally, Chapter 6 contains the first analysis of liquidity and transaction costs in the European carbon futures market. Results presented in Chapter 6 show a marked increase in liquidity and an ensuing reduction in transaction costs as the carbon market matures over time. Carbon futures also experience substantial price volatility, consistent with prior studies of new and emerging markets. Furthermore, results presented in the chapter provide evidence of a permanent price effect associated with medium and large trades in carbon futures, suggesting these trades reveal some degree of price information to the market.

The results reported in Chapter 6 have several public policy implications, as futures markets play a vital role in emissions trading schemes. Futures markets facilitate carbon risk transfer and price discovery, as well as providing a forward curve for the marginal cost of abatement. The detrimental effects of information asymmetry on price volatility and bid-ask spreads reported in the chapter highlight the need for market regulators to ensure the timely dissemination of all price-sensitive information in carbon markets. In addition, the documented permanent price effect associated with medium and large trades suggests that there is potential for insider dealing in this market, and thus the need for strict controls on illegal trading practices.

Appendix

The impact of the global credit crisis on Australian interest rate futures

This Appendix contains work completed during my candidature but not directly related to the topic of my dissertation.

A.1 Introduction

In a letter to investors dated early June 2007, a Bear Stearns hedge fund reported a 23 per cent fall in value since the beginning of the year. The fund, known as the High-Grade Structured Credit Strategies Enhanced Leverage Fund, invested predominantly in sub-prime securities. The effective failure of this fund and another linked Bear Stearns hedge fund highlighted the risk inherent in sub-prime debt, and brought what began as the sub-prime crisis into the global media spotlight.

Repercussions from the downturn in the US housing market and subsequent defaults on sub-prime loans were experienced in markets all over the world. On 12 July, 2007 it became clear the sub-prime crisis had reached Australia. It was on this date that Basis Capital, an Australian hedge fund, reported a 14 per cent loss on their Basis Yield Alpha Fund in the month of June alone. The Basis Yield Alpha Fund invested in sub-prime securities. Basis Capital simultaneously imposed withdrawal limits on clients to prevent a run on the fund. Approximately one week later they had suspended all withdrawals from the fund and revealed that the value of Basis Alpha had fallen to less than one half of its May 31 value.

The problems in sub-prime debt markets quickly led to a repricing of risk across all markets, with effects spilling over into prime debt markets, equity markets, and eventually the real economy. Debt markets were affected by a significant increase in funding costs and an absence of liquidity in the wholesale market. This flow-on effect to all debt markets is termed the 'global credit crisis' and is the focus of this appendix. Specifically, this appendix provides the first empirical analysis of the impact of the global credit crisis on Australian interest rate futures by examining volume, volatility, bid-ask spreads and depth.[124]

A.2 Data, sample, and research design

The data used in this study are sourced from Reuters and describe transactions executed in three SFE interest rate futures contracts from January 11, 2007 to January 13, 2008. The sample includes trades executed in 90-day Bank Accepted Bill futures (BABs), 3-year bond futures, and 10-year bond futures.[125] Each trade record contains fields which document the date, time, price, volume, best bid price and volume, and best ask price and volume

[124] This appendix does not discuss the global credit crisis in detail or provide an opinion on the appropriate regulatory, fiscal, and monetary policy responses.
[125] Contract specifications, including trading hours, are provided in Table 4-2 (p.91).

associated with each trade. Bid and ask quotes are the prevailing best quotes immediately prior to the trade.

The sample is restricted to trading in the near and deferred contracts. Trades occurring within five days of expiration of the near contract are excluded to minimise rollover effects.[126] Off-market block trades are removed from the sample as they arrive to the market crossed and in some instances reporting is delayed.[127]

To analyse the effects of the global credit crisis on Australian interest rate futures, the sample is divided into two six-month periods: January 11, 2007 to July 11, 2007 and July 13, 2007 to January 13, 2008. This assumes the global credit crisis first affected interest rate futures markets in Australia on July 12, 2007, the day the Australian hedge fund Basis Capital revealed its massive losses on sub-prime securities.

Within each sub-period four aspects of market quality are measured in both the day and the night trading sessions – volume, volatility, the bid-ask spread and depth at the best bid and ask.[128] These variables are defined in Table A-1 below.

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[126] See Frino and McKenzie (2002).

[127] Berkman et al. (2005) also remove block trades from their analysis of futures markets.

[128] Trading times for interest rate futures are provided in Table 4-2 (p.91).

Table A-1
Variable Definition

This table contains a description of the variables analysed in this appendix, including volume, volatility, the bid-ask spread, and depth. Each variable is measured separately for the day trading session and the night trading session.

Variable	Definition
Volume	Day: Number of contracts traded during the day trading session
	Night: Number of contracts traded during the night trading session
Volatility range	Day: (Daily high price – Daily low price)
	Night: (Night high price – Night low price)
Volatility ticks	Volatility range / Minimum tick
Bid-ask spread	Best ask price – best bid price
Depth	Best ask volume + best bid volume

A.3 Results

A.3.1 Volume and volatility

Table A-2 reports volume traded in the pre- and post-credit crisis periods for the 90-day BAB, 3-year bond and 10-year bond futures. Panel A reports volumes for day trading sessions and Panel B reports volumes for night trading sessions. The final column in Table A-2 tests if the difference between mean trading volumes in the pre- and post-periods is statistically significantly different from zero.

Table A-2
Day and night session volume: Pre- and post- credit crisis

This table reports the volume traded in 90-day BAB futures, 3-year bond futures, and 10-year bond futures for two sub-periods: the pre-credit crisis period and the post-credit crisis period. The pre-credit crisis period encompasses trades executed between 11 January, 2007 and 11 July, 2007, while the post-credit crisis period encompasses trades executed between 13 July, 2007 and 13 January, 2008. Volume is measured as the total number of contracts traded per trading session. Panel A reports volume traded in the day trading session and Panel B reports volume traded in the night trading session. The mean difference between pre- and post- credit crisis volumes is reported in the final column. T-statistics for this test are reported in parentheses.

		Volume (lots)		
		Pre-crisis	Post-crisis	Mean difference (T-stat)
Panel A: Day trading session				
90-day BAB	Mean	44,200.91	35,910.58	-8,290.32
futures	Median	29,844.00	31,189.50	(-1.58)
	Std Dev	45,159.22	22,984.64	
3-year bond	Mean	64,353.07	56,575.19	-7,777.89
futures	Median	52,885.00	50,730.00	(-1.50)
	Std Dev	40,264.19	29,204.01	
10-year bond	Mean	31,639.89	30,781.99	-857.90
futures	Median	26,184.00	26,968.50	(-0.24)
	Std Dev	30,516.33	14,026.90	
Panel B: Night trading session				
90-day BAB	Mean	11,868.60	10,518.91	-1,349.70
futures	Median	9,710.00	8,376.00	(-1.00)
	Std Dev	9,919.28	8,465.81	
3-year bond	Mean	23,667.64	26,721.01	3,053.37
futures	Median	22,288.50	24,048.00	(1.73)
	Std Dev	11,339.68	12,479.58	
10-year bond	Mean	13,274.20	16,492.63	3,218.42
futures	Median	12,425.50	15,913.50	(2.74)
	Std Dev	6,746.00	8,848.76	

In Panel A of Table A-2, average day session trading volumes decrease in the post-credit crisis period for all three contracts. The most notable difference occurs in the 90-day BAB futures contract. Prior to the onset of the global credit crisis in June 2007, the average daily volume traded in 90-day BAB futures was 44,200.91 contracts. In the post-credit crisis period average daily volume declined to 35,910.58 contracts – a decline of approximately 8,290.33 contracts (18.76 per cent). The decrease in average day session trading volume across all three contracts in Panel A of Table A-2 is not statistically significant.

Conversely, average volume increases in the night trading session for 3- and 10-year bond futures post-credit crisis. Panel B of Table A-2 shows volume traded in the night session increased by approximately 3,053.37 contracts for 3-year bond futures and 3,218.42 contracts for 10-year bond futures. Only the increase in 10-year bond futures volume is statistically significant. One possible explanation for this increase in trading activity is the additional volatility experienced by 3- and 10-year bond futures during overnight trading following the credit crisis. An increase in volatility in futures markets creates profit opportunities, and is likely to have encouraged US and European hedge funds to participate in the overnight market. Volatility is discussed in detail below.

Table A-3
Day and night session price volatility: Pre- and post- credit crisis

This table reports the price volatility of 90-day BAB futures, 3-year bond futures, and 10-year bond futures for two sub-periods: the pre-credit crisis period and the post-credit crisis period. The pre-credit crisis period encompasses trades executed between 11 January, 2007 and 11 July, 2007, while the post-credit crisis period encompasses trades executed between 13 July, 2007 and 13 January, 2008. *Volatility Range* is the difference between the session high price and the session low price, and is measure in yield points p.a. *Volatility Ticks* is the volatility range divided by the minimum tick for each contract, and is measured in ticks. Panel A reports volatility in the day trading session and Panel B reports volatility in the night trading session. The mean difference between pre- and post- credit crisis volatilities is reported in the final column. T-statistics for this test are reported in parentheses.

		Volatility range (yield pts p.a.)			Volatility ticks (ticks)		
		Pre-crisis	Post-crisis	Difference (T-stat)	Pre-crisis	Post-crisis	Difference (T-stat)
Panel A: Day trading session							
90-day BAB futures	Mean	0.053	0.054	0.001	5.266	5.382	0.115
	Median	0.030	0.050	(3.54)	3.000	5.000	(3.54)
	Std Dev	0.051	0.034		5.128	3.436	
3-year bond futures	Mean	0.050	0.067	0.016	10.098	13.319	3.221
	Median	0.035	0.055	(65.72)	7.000	11.000	(65.72)
	Std Dev	0.039	0.058		7.776	11.528	
10-year bond futures	Mean	0.043	0.058	0.015	8.602	11.504	2.902
	Median	0.040	0.055	(135.98)	8.000	11.000	(135.98)
	Std Dev	0.022	0.028		4.350	5.513	
Panel B: Night trading session							
90-day BAB futures	Mean	0.037	0.045	0.009	3.679	4.536	0.857
	Median	0.030	0.040	(21.16)	3.000	4.000	(21.16)
	Std Dev	0.034	0.025		3.369	2.548	
3-year bond futures	Mean	0.052	0.078	0.026	10.454	15.620	5.166
	Median	0.045	0.075	(112.97)	9.000	15.000	(112.97)
	Std Dev	0.031	0.034		6.189	6.777	
10-year bond futures	Mean	0.057	0.084	0.027	11.454	16.766	5.312
	Median	0.050	0.075	(135.42)	10.000	15.000	(135.42)
	Std Dev	0.031	0.037		6.102	7.484	

Table A-3 reports two measures of price volatility for the pre- and post-credit crisis periods. The first measure of price volatility, volatility range, is the difference between the daily high and low price for each contract. The second measure, volatility ticks, is the daily volatility range divided by the minimum tick for each contract. Price volatility is measured for both day trading sessions (Panel A) and night trading sessions (Panel B).

As expected, the volatility of 90-day BAB futures, 3-year bond futures, and 10-year bond futures increases in the post-credit crisis period. Volatility increases during day and night trading sessions, and this increase in volatility is statistically significantly different from zero at the 0.01 level for all three interest rate futures contracts. This increase in volatility reflects the increasing uncertainty in interest rate markets following the onset of the global credit crisis.

A comparison of Panel A and Panel B in Table A-3 shows that volatility increases substantially more in the night trading session when compared with the day trading session. For example, average daily volatility for 3-year bond futures increases by 13.319 ticks in the day session and 15.620 ticks in the night session. This is most likely a result of the overlap of US and European day trading with the Australian overnight market. Important announcements concerning the credit crisis in the US and Europe took place during their respective business hours, ensuring that the immediate price reaction and associated interest rate volatility is present in the Australian overnight trading session.

A.3.2 Bid-ask spreads and depth

Table A-4 reports the bid-ask spread for 90-day BAB futures, 3-year bond futures, and 10-year bond futures in the pre- and post-credit crisis periods. Panel A reports bid-ask spreads during day session trading and Panel B reports bid-ask spreads during night session trading.

The average bid-ask spread of all three interest rate futures contracts is wider during the post-credit crisis period. Table A-4 reports a positive and statistically significant difference between mean spreads pre-and post-credit crisis for both day and night trading sessions. The widening of bid-ask spreads in response to the global credit crisis is consistent with information-based models of the bid-ask spread.[129] The onset of the global credit crisis greatly increased information asymmetry in interest rate markets and the widening of bid-ask spreads post-credit crisis reflects this.

[129] See Glosten and Milgrom (1985) and Easley and O'Hara (1987).

Table A-4
Day and night session bid-ask spreads: Pre- and post- credit crisis

This table reports the bid-ask spread for 90-day BAB futures, 3-year bond futures, and 10-year bond futures for two sub-periods: the pre-credit crisis period and the post-credit crisis period. The pre-credit crisis period encompasses trades executed between 11 January, 2007 and 11 July, 2007, while the post-credit crisis period encompasses trades executed between 13 July, 2007 and 13 January, 2008. The bid-ask spread is measured as the difference between the best ask price and best bid price immediately prior to each trade, and is measured in yield point p.a. Panel A reports the bid-ask spread in the day trading session and Panel B reports the bid-ask spread in the night trading session. The mean difference between pre- and post- credit crisis bid-ask spreads is reported in the final column. T-statistics for this test are reported in parentheses.

		Bid-ask spread (yield pts p.a.)		
		Pre-crisis	Post-crisis	Mean difference (T-stat)
Panel A: Day trading session				
90-day BAB futures	Mean	0.0101	0.0103	0.00023
	Median	0.0100	0.0100	(12.86)
	Std Dev	0.0014	0.0035	
3-year bond futures	Mean	0.0051	0.0051	0.00004
	Median	0.0050	0.0050	(5.13)
	Std Dev	0.0010	0.0021	
10-year bond futures	Mean	0.0051	0.0051	0.00003
	Median	0.0050	0.0050	(6.31)
	Std Dev	0.0009	0.0011	
Panel B: Night trading session				
90-day BAB futures	Mean	0.0105	0.0113	0.00081
	Median	0.0100	0.0100	(18.89)
	Std Dev	0.0020	0.0044	
3-year bond futures	Mean	0.0053	0.0056	0.00031
	Median	0.0050	0.0050	(24.01)
	Std Dev	0.0015	0.0022	
10-year bond futures	Mean	0.0054	0.0056	0.00015
	Median	0.0050	0.0050	(14.47)
	Std Dev	0.0017	0.0019	

As with volatility, bid-ask spreads widen substantially more in the night session. For example, the increase in the bid-ask spread for 3-year bond futures during the night session was over seven times greater than the increase in the day session. This difference is also likely to result from the overlap of the US and European day trading session and the Australian night trading session.

Table A-5 reports depth at the best bid and offer pre- and post-credit crisis for 90-day BAB futures, 3-year bond futures, and 10-year bond futures. As in previous tables, Panel A reports day trading and Panel B reports overnight trading.

Average depth at the best bid and offer is considerably lower in the post-credit crisis period for all interest rate futures contracts, and the reduction in depth is statistically significant at the 0.01 level. Panel A of Table A-5 shows that average depth during day trading decreased from 9,353.17 contracts to 2,755.42 contracts for 90-day BAB futures – a 70.54 per cent decline. Average depth during the day session also decreased for 3- and 10-year bond futures. 3-year bond futures experienced a fall in average depth from 2,624.66 contracts to 1,372.12 contracts (a 47.92 per cent decline) and 10-year bond futures experienced a fall in average depth from 654.91 contracts to 482.05 contracts (a 29.24 per cent decline). Results are similar for the night trading session in Panel B.

Table A-5
Day and night session depth: Pre- and post- credit crisis

This table reports depth at the best quotes for 90-day BAB futures, 3-year bond futures, and 10-year bond futures for two sub-periods: the pre-credit crisis period and the post-credit crisis period. The pre-credit crisis period encompasses trades executed between 11 January, 2007 and 11 July, 2007, while the post-credit crisis period encompasses trades executed between 13 July, 2007 and 13 January, 2008. Depth is measured as the sum of the volume at the best bid price and the volume at the best ask price immediately prior to each trade. Panel A reports depth during the day trading session and Panel B reports depth during the night trading session. The mean difference between pre- and post- credit crisis depth is reported in the final column. T-statistics for this test are reported in parentheses.

		Depth (no. contracts)		
		Pre-crisis	Post-crisis	Mean difference (T-stat)
Panel A: Day trading session				
90-day BAB futures	Mean	9,353.17	2,755.42	-6,597.74
	Median	7,612.00	1,915.00	(-166.87)
	Std Dev	6,772.72	2,634.08	
3-year bond futures	Mean	2,634.66	1,372.12	-1,262.54
	Median	2,269.00	1,162.00	(-173.59)
	Std Dev	1,724.98	966.20	
10-year bond futures	Mean	984.83	696.71	-288.13
	Median	838.00	584.00	(-110.95)
	Std Dev	654.91	482.05	
Panel B: Night trading session				
90-day BAB futures	Mean	5,437.26	1,406.63	-4,030.63
	Median	3,932.00	933.00	(-72.59)
	Std Dev	5,303.88	1,549.38	
3-year bond futures	Mean	1,095.49	562.22	-533.27
	Median	832.00	405.00	(-91.10)
	Std Dev	992.44	521.79	
10-year bond futures	Mean	323.34	249.28	-74.06
	Median	259.00	193.00	(-52.42)
	Std Dev	259.35	216.89	

Given the uncertainty and volatility created by the global credit crisis, the reaction of market depth is unsurprising. In times of high volatility and uncertainty, traders are less willing to provide liquidity as there is an increased risk of adverse market movements. It is important to note that while the reduction in average depth in the post-credit crisis period appears extreme, the level of remaining depth is more than sufficient to accommodate very large trades in these contracts.

A.4 Conclusion

The global credit crisis has had a relatively large impact on Australian interest rate futures. The fear and uncertainty resulting from the crisis produced significantly lower day session volumes, higher volatility, wider bid-ask spreads and reduced depth at the best bid and offer for 90-day BAB futures, 3-year bond futures, and 10-year bond futures contracts. Conversely, night session volumes increased substantially for 3- and 10-year bond futures. This is likely a result of the large increase in volatility and hence profit opportunities during overnight trading.

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