Original Article

Liquidity and transaction costs in the European carbon futures market

Received (in revised form): 6th October 2009

Alex Frino
is CEO of the Capital Markets Co-Operative Research Centre and Professor of Finance at the University of Sydney. In 1991, he received a Masters Degree in Finance from the University of Cambridge, England, and in 1995 a PhD in Finance from the University of Sydney, Australia. He specialises in equity and derivatives market microstructure. He has published several articles in leading scholarly journals including the *Journal of Finance*, the *Journal of Banking & Finance*, the *Journal of Portfolio Management* and the *Journal of Futures Markets*.

Jennifer Kruk
is completing the final stages of her PhD in Finance at the University of Sydney and had a scholarship from the Sydney Futures Exchange throughout her candidature. She graduated with first class honours in finance from the University of Sydney in 2004 (BCom, Hons). She currently works as an associate analyst at Deutsche Bank in Sydney.

Andrew Lepone
is the director of the Futures Industry Research Centre at the Australian Securities Exchange and a senior lecturer at the University of Sydney where he lectures at both undergraduate and postgraduate levels. He completed his PhD at the University of Sydney in 2007. He has published articles in a number of academic journals including the *Journal of Banking and Finance* and the *Journal of Futures Markets.* His research focuses on the microstructure of futures and equities markets.

Correspondence: Andrew Lepone, Faculty of Economics and Business, University of Sydney, NSW 2006, Australia
E-mail: a.lepone@econ.usyd.edu.au

ABSTRACT **This article is the first to examine liquidity and transaction costs in the European carbon futures market. Results indicate a dramatic improvement in liquidity and a subsequent reduction in transaction costs since carbon futures began trading in 2005. 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 information asymmetry, and provide evidence of a permanent price effect following medium and large trades.**

Journal of Derivatives & Hedge Funds (2010) **16,** 100–115. doi:10.1057/jdhf.2010.8

Keywords: carbon futures; information asymmetry; transaction costs; regulation

INTRODUCTION

According to World Bank statistics, the European Union Emissions Trading Scheme (EU ETS) dominates the global carbon market. A total of 2061 million tonnes of carbon dioxide ($MtCO_2$) were traded via the EU ETS in 2007, worth approximately US$50.39 billion. This represents 97 per cent of total volume and 99 per cent of the total value traded on global allowance-based carbon markets in 2007.[1] Futures and forward contracts account for the majority of EU ETS volume, and therefore are the focus of this study. Specifically, we focus on European Climate Exchange Carbon Financial Instrument (ECX CFI) futures as they represent approximately 80 per cent of the exchange traded volume.[2]

ECX CFI futures possess several unique features that differentiate them from traditional futures contracts. First, their underlying asset, a European Union Allowance (EUA), is a product of legislation.[3] 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 private information in carbon futures markets. A select group of employees and auditors have knowledge of a firm's net position in EUAs before 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 2 years.

Despite these intriguing characteristics, an overwhelming majority of prior literature examines the environmental and political aspects of emissions trading. Only a handful of studies investigate emissions trading from a financial markets perspective. The common themes among financial market studies of emissions trading are carbon pricing, information asymmetry and uncertainty, and market efficiency and price discovery.[4–13]

The dearth of empirical research in this area is surprising. Most research focuses on the spot EUA market, even though it accounts for *only* 2 per cent of EU ETS trading volume. Futures markets are underrepresented in the literature. 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. This article attempts to rectify the imbalance in emissions trading literature by explicitly examining the European carbon futures market, with a specific focus on liquidity and transaction costs.

This article is organised as follows. Section 'The European carbon market' describes the EU ETS and the European Climate Exchange (ECX). Section 'Data and descriptive statistics' contains the data and descriptive statistics. Sections 'Trading activity and price volatility' and 'Transaction costs' report the results. Section 'Conclusions' presents the conclusions.

THE EUROPEAN CARBON MARKET

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 2005–2007, Phase II is the Kyoto period and includes the years 2008–2012 and Phase III is the post-Kyoto period and includes the years 2013–2020. 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.[14]

The EU ETS is designed as a cap and trade scheme. Before the commencement of each phase, Member States submit their annual emissions targets (the cap) to the European Commission for approval.[15] Once approved, the European Commission requires that Member States allocate 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 1 tonne of carbon dioxide, and there is a restriction on the number of permits Member States are allowed to auction.[16]

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.[17] The penalty for Phase I is 40 euro per missing EUA and for Phase II the penalty is 100 euro per missing EUA. Emissions data for a particular year are published by the European Commission in late April or early May the following year.

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 5 per cent occurring in the spot and options markets.[1] Exchange-based spot market trading is concentrated on Bluenext; however, trading is also available on Climex, the ECX, the European Energy Exchange, Energy Exchange Austria and Nord Pool. Futures trading is concentrated on the ECX, which uses the ICE Futures platform to trade its products. Bluenext and the European Energy Exchange also list futures contracts on EUAs.

European Climate Exchange Carbon Financial Instrument (ECX CFI) futures

The ECXoffers futures and options contracts on EUAs and futures contracts on Certified Emissions Reductions (CER).[18] 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. 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 1000 EUAs (1000 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 0.01 euro. The minimum tick decreased from 0.05 to 0.01 euro on 27 March 2007. Both monthly and yearly contracts are available.[19]

DATA AND DESCRIPTIVE STATISTICS

Data

The data used in this study are sourced from ICE and Reuters, and describe trading in ECX CFI futures.[20] The ICE data describe daily on-market and off-market volume from 22 April 2005 to 25 June 2008. The Reuters data describe all on-market transactions from 10 October 2005 to 16 June 2008.[21] Each trade record in the Reuters data contain fields that 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 before the trade.

Contracts of all maturities are included in the sample; however, the majority of the analysis in this article encompasses contracts expiring in December 2008. Trades reported in US dollars are included in the volume analysis, but are excluded from the price volatility and transaction cost analysis.[22]

Descriptive statistics

Table 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 1 and 600 contracts, respectively. The distribution of trade sizes across the sample suggests that the majority of

Table 1: Descriptive statistics

Contract	*Trade volume*		*Percentiles: Trade volume*							*N*
	Mean	*Std dev*	*Min.*	*10%*	*25%*	*50%*	*75%*	*90%*	*Max.*	
December 2005	13.08	20.70	1	5	9	10	10	20	375	1327
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	8280
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	3705
December 2010	7.850	10.57	1	1	1	5	10	20	194	1497
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	1174
Total sample	*8.580*	*11.49*	*1*	*1*	*2*	*5*	*10*	*20*	*600*	*116 559*

This table reports descriptive statistics for all the 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 1000 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.

on-market trades are small sizes, 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. Sections 'Trading activity and price volatility' and 'Transaction costs' examine ECX CFI December 2008 futures in detail.

TRADING ACTIVITY AND PRICE VOLATILITY

Trading volume: All expiry months

As a preliminary analysis of the level of trading activity in ECX CFI futures, Table 2 reports the total on-market volume traded in each contract.[23] To examine the changes in trading activity over time, the total volume is reported on a quarterly basis. Table 2 documents a dramatic improvement in the 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, respectively.[24] The improvement in on-market trading activity, reported in Table 2, is supported by the ICE data, which document a 102 per cent increase in the total number of contracts traded both on- and off-market since inception.

Table 2 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 the total quarterly trading volume. This concentration of liquidity in the December contracts coincides with the annual audit of company and Member State emissions. Second, trading volume in the December 2007 contracts deteriorates significantly during 2007. As Phase I EUAs were not fungible with Phase II EUAs, December 2007 futures traded at less than 1 euro for most of 2007. This most likely exacerbated the natural shift from trading Phase I to Phase II contracts.[25]

Third, the 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 onwards, 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 were four on-market trades executed in the December 2013 futures on 5 June 2008.

The descriptive statistics presented in Table 1 and results presented in Table 2 document limited on-market trading activity outside the December 2008 expiry month. Thus, the remainder of this article focuses on the December 2008 futures.

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 observe 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 distinct ways – daily volume, daily trade frequency and trade size. Daily volume is the number of contacts traded per day, daily trade

Table 2: On-market trading volume: All contracts

	Contract expiry month										
	December 2005	*December 2006*	*December 2007*	*December 2008*	*December 2009*	*December 2010*	*December 2011*	*December 2012*	*December 2013*	*Non-December*	*All contracts*
December Q 2005	17 354	14 998	3391	280	—	—	—	—	—	605	36 628
	(47.38%)	(40.95%)	(9.26%)	(0.76%)	—	—	—	—	—	(1.65%)	(100%)
March Q 2006	—	52 662	10 253	2800	45	—	35	20	—	5285	71 100
	—	(74.07%)	(14.42%)	(3.94%)	(0.06%)	—	(0.05%)	(0.03%)	—	(7.43%)	(100%)
June Q 2006	—	77 199	15 371	15 338	226	—	—	—	—	280	108 414
	—	(71.21%)	(14.18%)	(14.15%)	(0.21%)	—	—	—	—	(0.26%)	(100%)
September Q 2006	—	34 643	11 666	15 958	100	—	—	—	—	180	62 547
	—	(55.39%)	(18.65%)	(25.51%)	(0.16%)	—	—	—	—	(0.29%)	(100%)
December Q 2006	—	17 923	17 845	20 424	15	20	—	—	—	—	56 227
	—	(31.88%)	(31.74%)	(36.32%)	(0.03%)	(0.04%)	—	—	—	—	(100%)
March Q 2007	—	—	23 400	44 341	348	—	—	1	—	370	68 460
	—	—	(34.18%)	(64.77%)	(0.51%)	—	—	(0.00%)	—	(0.54%)	(100%)
June Q 2007	—	—	15 348	71 398	2466	126	323	143	—	—	89 804
	—	—	(17.09%)	(79.50%)	(2.75%)	(0.14%)	(0.36%)	(0.16%)	—	—	(100%)
September Q 2007	—	—	2401	98 188	6572	1733	735	2742	—	—	112 371
	—	—	(2.14%)	(87.38%)	(5.85%)	(1.54%)	(0.65%)	(2.44%)	—	—	(100%)
December Q 2007	—	—	7687	71 970	4458	1576	689	2271	—	2	88 653
	—	—	(8.67%)	(81.18%)	(5.03%)	(1.78%)	(0.78%)	(2.56%)	—	(0.00%)	(100%)
March Q 2008	—	—	—	132 020	8049	3693	1613	2538	—	2150	150 063
	—	—	—	(87.98%)	(5.36%)	(2.46%)	(1.07%)	(1.69%)	—	(1.43%)	(100%)
June Q 2008	—	—	—	138 825	7596	4604	1267	1455	40	1994	155 781
	—	—	—	(89.12%)	(4.88%)	(2.96%)	(0.81%)	(0.93%)	(0.03%)	(1.28%)	(100%)

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 1000 tonnes of carbon dioxide. The percentage of total quarterly on-market volume is reported in parentheses.

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 study 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, whereas daily returns are calculated using Reuters' opening and closing prices. The minimum tick is held constant at 0.05 euro to provide a consistent measure across the sample.[26] Table 3 reports trading activity and price volatility for the December 2008 futures contract on a quarterly basis.

Consistent with Table 2, Table 3 documents a substantial improvement in trading activity through time. The average daily trading volume

Table 3: Trading activity and price volatility: December 2008 futures

	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 (%)*	*Actual min tick (euro)*	*Min tick used (euro)*
December Q 2005	4.667	0.250	17.29	0.000	0.000	0.05	0.05
March Q 2006	43.08	2.600	16.79	5.194	0.009	0.05	0.05
June Q 2006	239.7	14.34	15.90	26.75	0.077	0.05	0.05
September Q 2006	245.5	13.86	15.60	6.571	0.016	0.05	0.05
December Q 2006	319.1	34.56	9.429	13.56	0.029	0.05	0.05
March Q 2007	692.8	71.91	9.328	14.08	0.035	0.05	0.05
June Q 2007	1116	137.4	7.989	23.50	0.044	0.01	0.05
September Q 2007	1511	171.3	8.725	14.42	0.026	0.01	0.05
December Q 2007	1107	140.0	7.940	10.83	0.017	0.01	0.05
March Q 2008	2096	369.3	5.802	15.68	0.027	0.01	0.05
June Q 2008	2571	398.8	6.827	12.47	0.018	0.01	0.05

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.

increases from 4.667 contracts per day in the December Quarter 2005 to 2 570.8 contracts per day in the June Quarter 2008, whereas 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.

Both measures of price volatility reported in Table 3 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 was to release the 2005 emissions data from all Member States in mid-May 2006; however, several Member States unofficially revealed they were net long EUAs between 24 April and 28 April (implying an over-supply of EUAs in the market).[27] The high level of information asymmetry and subsequent price volatility associated with these unofficial announcements continued until the European Commission released the 2005 emissions data on 15 May 2006. The price volatility experienced during the June Quarter 2006 demonstrates the adverse impact of information asymmetry on the carbon futures market.

TRANSACTION COSTS

Before 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.

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 study reports the quoted bid–ask spread immediately before 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 0.05 euro to provide a consistent measure across the sample. As a preliminary assessment of the implicit cost of trading, we also report effective spreads. The effective spread is measured in ticks and is defined as

$$Effective\ Spread_{i,t} = \left[\frac{VWAP\ Price_i - Midpoint_t}{MinTick}\right] \times D_i, \qquad (1)$$

where *VWAP Price* is the volume-weighted average price of trade i, *Midpoint* 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 0.05 euro.

In addition to the bid–ask spread and the effective spread, this article 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 4 reports bid–ask spreads, effective spreads and quoted depth at the best bid and best ask for the December 2008 contract.

Table 4: Bid-ask spreads, effective spreads and depth: December 2008 futures

	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)*
December Q 2005	0.550	11.00	5.500	10.00	14.33	0.05	0.05
March Q 2006	0.390	7.798	3.899	11.69	11.29	0.05	0.05
June Q 2006	0.652	13.04	6.530	15.67	10.66	0.05	0.05
September Q 2006	0.197	3.937	1.967	9.649	10.24	0.05	0.05
December Q 2006	0.129	2.578	1.288	10.90	12.39	0.05	0.05
March Q 2007	0.099	1.970	0.985	12.49	11.59	0.05	0.05
June Q 2007	0.083	1.654	0.827	10.92	11.91	0.01	0.05
September Q 2007	0.064	1.277	0.638	11.59	12.02	0.01	0.05
December Q 2007	0.057	1.135	0.567	10.40	10.05	0.01	0.05
March Q 2008	0.050	0.993	0.496	8.270	8.224	0.01	0.05
June Q 2008	0.043	0.870	0.438	8.198	7.525	0.01	0.05

This table reports bid-ask spreads, effective spreads, and depth at the best bid and ask 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 before each trade and is reported in both Euro 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 before 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.

Excluding the June Quarter 2006, the quoted bid–ask spread decreases monotonically over time. The quoted bid–ask spread decreases from 0.55 euro in the December Quarter 2005 to 0.043 euro in the June Quarter 2008; a decline of 92.1 per cent. A similar pattern occurs in the effective spread. When holding the minimum tick constant at 0.05 euro, the effective spread declines from 5.50 ticks in the December Quarter 2005 to 0.438 ticks in the June Quarter 2008.[28]

Consistent with information-based models, the bid–ask spread widens considerably during the June Quarter 2006.[29] This reflects the substantial information asymmetry present in the market, and suggests that it is necessary for carbon market regulators to implement measures to reduce information asymmetry, thereby allowing the market to function efficiently.

Table 4 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. There is almost no change in the available depth between the March and June Quarters of 2007, even though the minimum tick decreased from 0.05 to 0.01 euro on 27 March 2007.[30,31]

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 1 (<5 contracts) contains the smallest 60 per cent of trades, Group 2 (5–15 contracts) contains the next 30 per cent of trades and Group 3 (>15 contracts) contains the largest 10 per cent of trades. Similar to Kurov,[32] we calculate average trade-by-trade returns for 10 trades before and 30 trades after each transaction. Returns are calculated using the prevailing quote midpoints to mitigate the effects of bid–ask bounce.[33–38]

Figure 1 plots the cumulative average returns (CARs) surrounding trades in the December 2008 ECX CFI futures. Across all trade size groups, Figure 1 documents an upward return drift before buy trades and a downward return drift before sell trades of up to 10 basis points. Figure 1 also documents a post-trade price adjustment following all trades in the ECX CFI futures. That is, quotes are revised upward

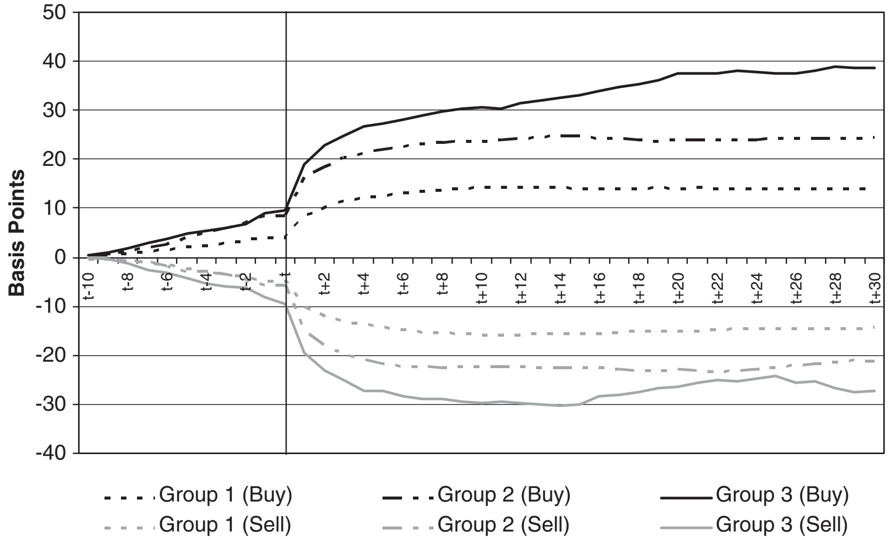

Figure 1: Cumulative average returns surrounding small, medium and large trades.
This figure documents cumulative average returns (CARs) surrounding transactions in three trade size groups. Group 1 contains the smallest 60 per cent of trades (<5 contracts), Group 2 contains the next 30 per cent of trades (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.

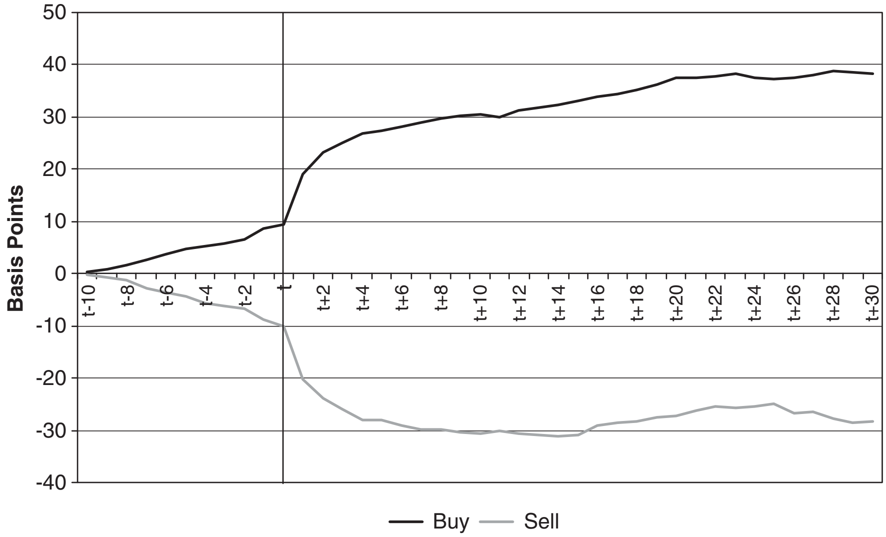

Figure 2: Cumulative average returns surrounding the largest 5 per cent of trades.
This figure documents cumulative average returns (CARs) surrounding the largest 5 per cent of trades (>20 contracts). Average returns are calculated using quotation midpoints and cumulated from 10 trades before to 30 trades after the transaction. Returns are reported separately for buyer- and seller-initiated trades.

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, in Group 2 are 24.48 (−21.65) basis points and in Group 3 are 38.69 (−27.31) basis points. All post-trade CARs are statistically significant at the 1 per cent level.

To determine the economic significance of CARs, we 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, whereas the total price adjustment surrounding trades in Groups 2 and 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 Groups 2 and 3. That is, these trades reveal some degree of information to the market, resulting in a new permanent price level.

To further examine price behaviour surrounding the largest trades, Figure 2 plots CARs for the largest 5 per cent of trades (>20 contracts). Similar to Figure 1, Figure 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 CARs in Figure 2 exceeds half the bid–ask spread, suggesting that there is a permanent price effect associated with both buys and sells in the largest 5 per cent of trades.

CONCLUSIONS

This article is the first to examine liquidity and transaction costs in the European carbon futures market, and documents several unique findings. Results show a marked increase in liquidity and ensuing reduction in transaction costs over time, and that liquidity is concentrated in the December expiry month contracts. This article also documents a substantial widening of the bid–ask spread in response to the leaking of the incomplete 2005 emissions data to the market. Finally, we present evidence of a permanent price effect associated with medium and large trades, suggesting that these trades reveal some degree of price information to the market.

These results have several public policy implications, as futures markets play a vital role in the EU ETS. 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 this article highlight the need for market regulators to ensure the timely dissemination of all price-sensitive information in carbon markets. In addition, the permanent price effect associated with medium and large trades documented in this article suggests that there is potential for insider dealing in this market, and thus the need for strict controls on illegal trading practices.

ACKNOWLEDGEMENTS

This research was funded by the Sydney Futures Exchange under Corporations Regulation 7.5.88(2). The authors thank the Intercontinental Exchange (ICE), the Securities Industry Research Centre for the Asia-Pacific (SIRCA) and Reuters for providing the data for this study. This article was improved by the comments of Anthony Collins, and seminar participants at the Australian Securities Exchange Seminar Series.

REFERENCES AND NOTES

1 See The World Bank. (2008) *State and Trends of the Carbon Market 2008*. Washington DC: The World Bank, The EU ETS is described in Section 'The European Union Emissions Trading Scheme (EU ETS)'.

2 According to the World Bank, less than 2 per cent of EU ETS trading occurred on the spot market, and between 2 and 3 per cent of trading involved options in 2007.

3 A European Union Allowance (EUA) gives the holder the right to emit 1 tonne of carbon dioxide. Each futures contract represents 1000 EUAs. ECX CFI contract specifications are provided in the Appendix.

4 Studies of carbon pricing include Mansanet-Bataller *et al*,[5] Sijm *et al*,[6] Alberola *et al*,[7] Convery and Redmond,[8] Daskalakis *et al*,[9] and Daskalakis and Markellos.[10] Studies of information asymmetry and uncertainty in the European carbon market include Mansanet-Bataller and Pardo[11] and Chevallier *et al.*[12] Studies of carbon market efficiency and price discovery include Daskalakis and Markellos[10] and Milunovich and Joyeux.[13]

5 Mansanet-Bataller, M., Pardo, A. and Valor, E. (2007) CO2 prices, energy and weather. *The Energy Journal* 28(3): 73–92.

6 Sijm, J., Neuhoff, K. and Chen, Y. (2006) Cost pass-through and windfall profits in the power sector. *Climate Policy* 6(1): 49–72.

7 Alberola, E., Chevallier, J., Chèze, B. and Campus, S. (2007) European Carbon Prices Fundamentals in 2005–2007: The Effects of Energy Markets, Temperatures and Sectorial Production. EconomiX Working Paper no. 2007-33.

8 Convery, F. and Redmond, L. (2007) Market and price developments in the European Union Emissions Trading Scheme. *Review of Environmental Economics and Policy* 1(1): 88.

9 Daskalakis, G., Psychoyios, D. and Markellos, R. (2009) Modeling CO2 emission allowance prices and derivatives: Evidence from the European trading scheme. *Journal of Banking and Finance* 33(7): 1230–1241.

10 Daskalakis, G. and Markellos, R. (2009) Are electricity risk premia affected by emission allowance prices? Evidence from the EEX, Nord Pool and Powernext. *Energy Policy* 37(7): 2594–2604.

11 Mansanet-Bataller, M. and Pardo, A. (2007) The Effects of National Allocation Plans on Carbon-markets. University of Valencia. Working Paper.
12 Chevallier, J., Ielpo, F. and Mercier, L. (2009) Risk aversion and institutional information disclosure on the European carbon market: A case-study of the 2006 compliance event. *Energy Policy* 37(1): 15–28.
13 Milunovich, G. and Joyeux, R. (2007) Market Efficiency and Price Discovery in the EU Carbon Futures Market. Macquarie University. Working Paper.
14 See the European Commission's website, http://ec.europa.eu/environment/climat/emission.htm.
15 Emissions targets are submitted in a formal document called a National Allocation Plan. Details of EUA allocations for Phase II are in Appendix B.
16 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.
17 Firms can also obtain Certified Emissions Reduction (CER) units from investing in greenhouse gas reducing projects through the Clean Development Mechanism. Once 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.
18 CER futures began trading in March 2008.
19 Contract specifications are provided in the Appendix.
20 The 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 study utilises Reuters data.
21 ECX CFI futures began trading on 22 April 2005; however, we were unable to obtain Reuters data before 10 October 2005.
22 Trades in US dollars represent less than 1 per cent of the sample.
23 An analysis of the ICE data show that the average proportion of daily on-market volume to daily off-market volume is 39.04 per cent.
24 Note that the data for the June Quarter 2008 do not encompass trades after 16 June 2008.
25 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.
26 On 27 March 2007 the minimum tick decreased from 0.05 to 0.01 euro.
27 This followed a record high ECX CFI futures price on 19 April.
28 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.
29 See Glosten, L.R. and Milgrom, P.R. (1985) Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics* 14(1): 71–100.
30 Goldstein and Kavajecz[31] 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.
31 Goldstein, M.A. and Kavajecz, K.A. (2000) Eighths, sixteenths, and market depth: Changes in tick size and liquidity provision on the NYSE. *Journal of Financial Economics* 56(1): 125–149.
32 Kurov, A. (2005) Execution quality in open-outcry futures markets. *Journal of Futures Markets* 25(11): 1067–1092.
33 See Harris,[34] Forester *et al*,[35] Lease *et al*,[36] Bhardwaj and Brooks,[37] and Cox and Peterson[38] for a discussion of the use of quotation midpoints to mitigate the effects of bid–ask bounce.
34 Harris, L. (1989) A day-end transaction price anomaly. *Journal of Financial and Quantitative Analysis* 24(1): 29–45.
35 Foerster, S., Keim, D. and Porter, D. (1990) Intraday Spreads, Returns and Variances: Tests of the Informed Trader Hypothesis. Unpublished Working Paper, University of Western Ontario.
36 Lease, R.C., Masulis, R.W. and Page, J.R. (1991) An investigation of market microstructure impacts on event study returns. *Journal of Finance* 46(4): 1523–1536.
37 Bhardwaj, R.K. and Brooks, L.D. (1992) The January anomaly – Effects of low share price, transaction costs, and bid-ask bias. *Journal of Finance* 47(2): 553–575.
38 Cox, D.R. and Peterson, D.R. (1994) Stock returns following large one-day declines – Evidence on short-term reversals and longer-term performance. *Journal of Finance* 49(1): 255–267.

APPENDIX A

Table A1 reports the contract specifications for ECX CFI futures.

Table A1: Contract specifications for ECX CFI futures

Contract	*ECX CFI futures*
Unit of trading	1 lot=1000 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)[a]
Max. price fluctuation	No limit
Contract months	Monthly: September 2006 – 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 3 days after last trading day (LTD + 3 delivery)
Margin	All open contracts marked-to-market daily

[a]The tick size decreased from € 0.05 to € 0.01 on 27 March 2007.

Source: www.theice.com and the Handbook of World Stock, Derivative & Commodity Exchanges 2007.

APPENDIX B

Table B1 reports Phase II National Allocation Plans for each Member State of the European Union.

Table B1: Phase II national allocation plans for EU member states

Member State	*Phase I cap*	*Verified 2005 emissions*	*Phase II cap proposed in NAP*	*Phase II cap allowed by EC*	*Difference between EC & proposed (%)*	*CDM/JI limit Phase II (%)*	*CDM/JI limit Phase II*
Austria	33	33.4	32.8	30.7	−6.40	10	3.1
Belgium	62.1	55.6	63.3	58.5	−7.60	8	4.9
Bulgaria[a]	42.3	40.6	67.6	42.3	−37.40	13	5.3
Cyprus	5.7	5.1	7.1	5.5	−23.00	10	0.5
Czech Rep.	97.6	82.5	101.9	86.80	−14.80	10	8.7
Denmark	33.5	26.5	24.5	24.5	0.00	17	4.2
Estonia	19	12.6	24.4	12.7	−47.80	0	0
Finland	45.5	33.1	39.6	37.6	−5.10	10	3.8
France	156.5	131.3	132.8	132.8	0.00	14	17.9
Germany	499	474	482	453.1	−6.00	20	90.8
Greece	74.4	71.3	75.5	69.1	−8.50	9	6.2
Hungary	31.3	26	30.7	26.9	−12.40	10	2.7
Ireland	22.3	22.4	22.6	22.3	−1.30	10	2.2
Italy	223.1	225.5	209	195.8	−6.30	15	29.4
Latvia	4.6	2.9	7.7	3.4	−55.50	10	0.3
Lithuania	12.3	6.6	16.6	8.8	−47.00	20	1.8
Luxembourg	3.4	2.6	4	2.5	−36.70	10	0.3

Malta	2.9	2	3	2.1	−29.10	NA	—
Netherlands	95.3	80.4	90.4	85.8	−5.10	10	8.6
Poland	239.1	203.1	284.6	208.5	−26.70	10	20.9
Portugal	38.9	36.4	35.9	34.8	−3.10	10	3.5
Romania[a]	74.8	70.8	95.7	75.9	−20.70	10	7.6
Slovakia	30.5	25.2	41.3	30.9	−25.20	7	2.2
Slovenia	8.8	8.7	8.3	8.3	0.00	16	1.3
Spain	174.4	182.9	152.7	152.3	−0.30	20	30.5
Sweden	22.9	19.3	25.2	22.8	−9.50	10	2.3
UK	245.3	242.4	246.2	246.2	0.00	8	19.7
Total	2298.50	2122.20	2325.30	2080.90	−10.50	—	278.7

[a]At the time Deutsche Bank published their report, the 2005 emissions data for Romania and Bulgaria were unverified.

This table reports details of the National Allocation Plans submitted by Member States to the European Commission for Phase II of the EU ETS. *Phase I cap* is the EC approved annual carbon dioxide emissions cap during Phase I of the EU ETS, *Verified 2005 emissions* are actual carbon dioxide emissions during 2005, *Phase II cap proposed in NAP* is the annual carbon dioxide emissions cap submitted to the EC for approval for Phase II of the EU ETS, and *Phase II cap allowed by EC* is the annual carbon dioxide emissions cap allowed by the EC. All caps are measured in million tonnes of carbon dioxide ($MtCO_2$). *Difference between EC & proposed* is the percentage difference between the Phase II cap proposed by the Member State and the cap mandated by the EC. *CDM/JI limit Phase II* is the limit on the import of Clean Development Mechanism (CDM) and Joint Implementation (JI) credits into the scheme as both a percentage and in $MtCO_2$.

NA: not applicable.

Source: Deutsche Bank and the European Commission.