TRANSACTION COSTS IN THE EUROPEAN CARBON FUTURES MARKET

ALEX FRINO[a*], JENNIFER KRUK[b], ANDREW LEPONE[c]

Working Paper: Do not quote
30 June, 2008

Abstract

This paper is the first to examine transaction costs in the European carbon futures market. Specifically, we estimate volume, volatility, bid-ask spreads, depth, and market impact costs for European Climate Exchange Carbon Financial Instrument futures. Results show a dramatic increase in liquidity and subsequent reduction in transaction costs over time and highlight the negative effects of information asymmetry on price volatility and bid-ask spreads. The observed statistically significant permanent price effect following trades in ECX CFI futures suggests that trades are executed by informed traders and contain information.

JEL Classification: G12, G14

This research was funded by the Sydney Futures Exchange under Corporations Regulation 7.5.88(2). The authors wish to thank Anthony Collins for useful comments, seminar participants at the Australian Securities Exchange, Nathan Williams for programming assistance, and ICE Futures, SIRCA and Reuters for providing the data.
*Corresponding Author: Finance Discipline, Faculty of Economics and Business, University of Sydney, NSW, 2006, Australia. Tel +61 2 9227 0889. Fax +61 2 9352 6461. Email: afri1432@usyd.edu.au

[a] *Alex Frino is a Professor in the Faculty of Economics and Business at the University of Sydney, Australia.*
[b] *Jennifer Kruk is a Ph.D. candidate in the Faculty of Economics and Business at the University of Sydney, Australia.*
[c] *Andrew Lepone is a Senior Lecturer in the Faculty of Economics and Business at the University of Sydney, Australia.*

1. Introduction

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.[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% of 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, private information in carbon futures markets is analogous to that in equity markets. A select group employees and auditors will have knowledge of a firm's net position in EUAs prior to the market, creating the need for stringent monitoring of insiders. Third, the most liquid ECX CFI

[1] See The World Bank: State and Trends of the Carbon Market 2008. The EU ETS is described in the following section.
[2] 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.
[3] A European Union Allowance (EUA) gives the holder the right to emit one tonne of CO_2. Each futures contract represents 1,000 EUAs. ECX CFI contract specifications are provided in Appendix 1.

futures contract, the December 2008 contract, was trading without a spot market for approximately two 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 (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, Daskalakis and Markellos, 2007a), information asymmetry and uncertainty (Mansanet-Bataller and Pardo, 2007; Chevallier, Ielpo, and Mercier, 2008), and market efficiency and price discovery (Daskalakis and Markellos, 2007b; Milunovich and Joyeux, 2007).

The dearth of empirical microstructure research in this area is surprising. Interestingly, most research to date focuses on the spot EUA market even though it accounts for only two per cent of EU ETS trading volume. In spite of their important role, futures markets are relatively 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 paper attempts to rectify the imbalance in emissions trading literature by explicitly examining the microstructure of the European carbon futures market, with a specific focus on transaction costs.

The paper is organised as follows. Section 2 describes the European carbon market and Section 3 contains the data and descriptive statistics. Section 4 and Section 5 describe the results, and Section 6 presents the conclusions. The Appendix contains the contract specifications for ECX CFI futures and details of National Allocation Plans.

2. The European carbon market

2.1 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 almost 50 per cent of all European Union emissions.[4]

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.[5] Once approved, the European Commission requires that Member States allocate European Union Allowances (EUAs) to firms covered by the scheme no later than the end of February each year. One EUA gives

[4] These statistics are provided on the European Commission's website.
[5] Emissions targets are submitted in a formal document called a National Allocation Plan. Details of EUA allocations for Phase II are in Appendix 2.

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.[6]

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.[7] 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 is 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 split between the spot market and the options market.[8] 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

[6] 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.
[7] 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.
[8] The World Bank: State and Trends of the Carbon Market 2008.

products. Bluenext and the European Energy Exchange also list futures contracts on EUAs.

2.2. European Climate Exchange Carbon Financial Instrument (ECX CFI) futures

The European Climate Exchange (ECX) offers futures and options contracts on EUAs and futures contracts on CERs.[9] ECX CFI futures are by far 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 some of Europe's biggest 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 0.01 Euro. The minimum tick decreased from 0.05 Euro to 0.01 Euro on 27 March, 2007. Both monthly and yearly contracts are available. Contract specifications are provided in full in Appendix 1.

[9] CER futures began trading in March 2008.

3. Data and descriptive statistics

3.1 Data

The data used in this study are sourced from ICE and Reuters. ICE data is used only to determine the proportion of trades executed on-market; the remainder of the analysis in this study utilises Reuters data. The ICE data describe daily on-market and off-market volume in all ECX CFI futures contracts from April 22, 2005 to June 25, 2008. The Reuters data describe all on-market transactions executed in ECX CFI futures contracts from October 10, 2005 to June 16, 2008.[10] Each trade record 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.

Contracts of all maturities are included in the sample; however, the majority of the analysis in this paper uses data for the December 2008 contact. Trades reported in US dollars are included in the volume analysis but excluded from the price volatility and transaction cost analysis.[11]

3.2 Descriptive statistics: Reuters data

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

[10] ECX CFI futures began trading on April 22, 2005.
[11] Trades in US dollars represent less than 1 per cent of the sample.

< INSERT TABLE I HERE >

Trades in the December 2008 futures contract account for approximately 70.1 per cent of all trades in the sample. Table I shows that the sample contains 82,646 on-market trades in this contract, and each trade has an average volume of 7.4 contracts. On-market trades in December 2008 futures range from a minimum of one contract to a maximum of 500 contracts. Section 4 and Section 5 examine ECX CFI December 2008 futures in detail.

4. Trading activity and price volatility

4.1 Trading volume: All contracts

As a preliminary analysis of the level of trading activity in ECX CFI futures, Table II reports the total on-market volume traded in each contract.[12] To observe changes in trading activity over time, total volume is reported on a quarterly basis.

< INSERT TABLE II HERE >

As expected, Table II shows a dramatic improvement in on-market trading activity over time. This is especially noticeable in the March and June Quarters of 2008.[13] The improvement in on-market trading activity reported in Table II is supported by ICE data which shows a 102 per cent increase in the total number of contracts traded both on-and off-market since inception.

[12] 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.
[13] Note that the June Quarter 2008 ends on June 16, 2008.

Several interesting results arise from Table II. First, trading volume in the December 2007 contract deteriorates significantly during 2007. The European Commission's rejection of a plan by the French and Polish governments to bank unused Phase I EUAs for use in Phase II exacerbated the shift in trading from Phase I to Phase II contracts.[14] As a result, the December 2007 futures price was less than 1 Euro for the majority of 2007. Second, even though Phase III emissions caps are unknown, there were four on-market trades executed in December 2013 futures on June 5, 2008. Third, December 2008 futures are by far the most liquid ECX CFI futures contract. This contract 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.

The descriptive statistics presented in Table I and results presented in Table II show that there is little on-market trading activity outside the December 2008 contract. It is for this reason that the remainder of this paper focuses on the December 2008 contract.

4.2 Trading activity and price volatility: December 2008 futures

A high level of trading activity is indicative of a well functioning and liquid futures market. In order 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 ways – daily volume, daily trade frequency, and average trade size. Daily volume is the number of contacts traded per day and daily trade frequency is the number of trades per day. If the December 2008 contract does

[14] World Bank: State and Trends of the Carbon Market 2006

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. Average trade size is the daily volume divided by the daily trade frequency on days that trading occurs and therefore is not assigned a value of zero on days with no trading.

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, while daily returns are calculated using Reuters opening and closing prices. Table III reports trading activity and price volatility for the December 2008 futures contract on a quarterly basis.

< INSERT TABLE III HERE >

Consistent with Table II, Table III demonstrates a substantial improvement in trading activity over time. The mean daily trading volume increases from 4.667 contracts per day in the December Quarter 2005 to 2,570.833 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 398.778 trades per day in the June Quarter 2008. Interestingly, the average trade size decreases over time from 17.292 lots in the December Quarter 2005 to 6.827 lots in the June Quarter 2008.

Both measures of price volatility reported in Table III show that volatility is highest for December 2008 futures 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 intended to release 2005 emissions data from all Member States in mid-May 2006; however, following a record high futures price on April 19, several Member States unofficially revealed they were net long EUAs between April 24 and April 28 (implying an over-supply of EUAs in the market). The price volatility associated with the unofficial release of 2005 emissions data continued until the European Commission made an official announcement on May 15, 2006. The severe price volatility experienced during the June Quarter 2006 demonstrates the adverse affect information asymmetry has on the carbon futures market.

5. Transaction costs

Prior to analysing transaction costs, trades are classified as buyer-or seller-initiated using a quote-based rule. That is, 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 the analysis of market impact costs.

5.1 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 study 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. The minimum tick is held constant at 0.05 Euro to provide a consistent measure across the sample.[15] 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

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

where *VWAP Price*$_i$ 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. As with the bid-ask spread analysis, the minimum tick is held constant at 0.05 Euro throughout the sample.

In addition to the bid-ask spread and the effective spread, this paper also reports 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. If this is not the case, they will incur increased market impact costs. Table IV below reports bid-ask spreads, effective spreads, and depth at the best bid and best ask for the December 2008 contract.

< INSERT TABLE IV HERE >

Excluding the June Quarter 2006, the quoted bid-ask spread decreases monotonically over time. The quoted bid-ask spread decreases from 0.55 Euro (11 ticks) in the

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

December Quarter 2005 to 0.043 Euro (0.87 ticks) in the June Quarter 2008; a decline of 92.1 per cent. A similar pattern occurs in the effective spread. The effective spread declines from 5.50 ticks in the December Quarter 2005 to 0.438 ticks in the June Quarter 2008. The effective spread is almost always equal to half the quoted spread in each quarter, suggesting that on-market trades in ECX CFI December 2008 futures on average do not incur market impact costs in excess of the bid-ask spread.

Consistent with information-based models of the bid-ask spread, the bid-ask spread for December 2008 futures widens considerably during the June Quarter 2006.[16] This reflects the substantial information asymmetry present in the market at the time, suggesting that it is necessary for carbon market regulators to implement measures to reduce information asymmetry, therefore allowing the market to function efficiently.

Table IV also reports the mean depth at the best prevailing ask price and the best prevailing bid price for each quarter in the sample. Depth remains relatively unchanged over time and there is little difference between the mean lot size available at the best ask price and the mean lot size available at the best bid price. Interestingly, there is almost no change in available depth between the March and June Quarters of 2007 even though the minimum tick decreased from 0.05 Euro to 0.01 Euro on March 27, 2007. From the December Quarter 2006 onwards, there is sufficient depth at the best bid and best ask to accommodate the average trade size.

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

5.2 Market impact costs: December 2008 futures

Market impact costs are an implicit cost of trading, capturing the difference between the price of a trade and the price that would have prevailed had the trade not executed (Domowitz, Glen, and Madhavan, 2001). Market impact costs measure the total implicit cost of trading, and encompass a temporary liquidity effect and a permanent information effect (Kraus and Stoll, 1972).

To analyse market impact costs across 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.

Table IV reports one measure of market impact costs – the effective spread.[17] Jones and Lipson (2001) discuss several problems associated with effective spreads; one being that an effective spread will underestimate market impact costs if news of an incoming block trade is leaked to the market. To mitigate this problem, market impact costs are also computed using a pre-trade benchmark, analogous to Berkman, Brailsford, and Frino (2005). That is, market impact costs (*Total)* are defined as

$$Total_{i,t} = [(VWAP\ Price_i - Price_{t-5}) / MinTick] * D_i . \qquad (2)$$

The two components of market impact costs, the liquidity (*Temporary*) and information (*Permanent*) effects, are defined as

[17] Jones and Lipson (2001) use the effective spread as a measure of market impact costs.

$$Temporary_{i,t} = \left[(Price_{t+5} - VWAP\ Price_i) / MinTick\right] * D_i \quad (3)$$

$$Permanent_{i,t} = \left[(Price_{t+5} - Price_{t-5}) / MinTick\right] * D_i, \quad (4)$$

where *VWAP Price*$_i$ is the volume-weighted average price of trade *i*, P_{t-5} is the price of the trade five trades prior to trade *i*, P_{t+5} is the price of the trade five trades prior to trade *i*, *MinTick* is the minimum price increment, and D_i is 1 for buys and -1 for sells. Panel A of Table V reports estimates of total, temporary, and permanent price effects for small, medium, and large trades. As a robustness test, Panel B of Table V reports these same estimates using prices ten trades before and after trade *i* as the benchmark prices.

< INSERT TABLE V HERE >

The total price effect reported in Panel A of Table V increases monotonically as trade size increases and is statistically significant at the 0.01 level for all trade size groups. This suggests that large trades incur greater market impact costs, consistent with prior futures market empirical studies.[18] Interestingly, only trades in the small trade size group (<5 contracts) exhibit a statistically significant price reversal. There is no evidence of a price reversal for medium and large trades – these trades exhibit price continuation. Regardless of whether a price reversal is present, all trade size groups report a positive and statistically significant permanent price effect. This suggests that trades of all sizes in ECX CFI futures are executed by informed traders and contain

[18] See Frino and Oetomo (2005) for an analysis of market impact costs for stock index and interest rate futures contracts.

information. Results are similar for buyer-and seller-initiated trades and across benchmarks.

6. Conclusions

The EU ETS is the world's largest carbon market, with approximately USD 50.39 billion traded in 2007. In spite of the rapid growth of trading in the EU ETS, there is a dearth of empirical microstructure studies that examine emissions trading. This paper is the first to analyse transaction costs in the European carbon futures market. Our results show a marked increase in liquidity and ensuing reduction in transaction costs over time. Interestingly, this study reports a positive and statistically significant permanent price effect following trades of all sizes, suggesting trades in ECX CFI futures are executed by informed traders and contain information.

Our results have several public policy implications. The detrimental effects of information asymmetry on price volatility and bid-ask spreads highlight the need for market regulators to ensure the timely dissemination of all price-sensitive information. In addition, the positive and statistically significant permanent price effect suggests that market regulators need to closely monitor trading by insiders, as there is potential for inside information in this market.

Bibliography

Alberola, E., J. Chevallier, and B. Cheze, 2007, European carbon prices fundamentals 2005-2007: The effects of energy markets, temperatures, and sectorial production, *Working Paper*, University of Paris.

Berkman, H., T. Brailsford, and A. Frino, 2005, A note on execution costs for stock index futures: Information versus liquidity effects, *Journal of Banking and Finance* 29, 565–577.

Chevallier, J., F. Ielpo, and L. Mercier, 2008, Risk Aversion and Institutional Information Disclosure on the European Carbon Markets, *Working Paper,* University of Paris.
Convery, F. and L. Redmond, 2007, Market and Price Developments in the European Union Emissions Trading Scheme, *Review of Environmental Economics and Policy* 1, 88-111.
Daskalakis, G., D. Psychoyios, and R. Markellos, 2007a, Modelling CO2 Emission Allowance Prices and Derivatives: Evidence from the European Trading Scheme, *Working Paper,* Athens University.
Daskalakis, G. and R. Markellos, 2007a, Are Electricity Risk Premia affected by the Emission Allowance Prices? Evidence from the EEX, *Working Paper,* Athens University.
Daskalakis, G. and R. Markellos, 2007b, Are the European Carbon Markets Efficient?, *Working Paper,* Athens University.
Domowitz, I., J. Glen, and A. Madhavan, 2001, Liquidity, volatility and equity trading costs across countries and over time, *International Finance* 4, 221–255.
Easley, D. and M. O'Hara, 1987, Price, Trade Sieze, and Information in Securities Markets, *Journal of Financial Economics* 19, 69-90.
Frino, A. and T. Oetomo, 2005, Slippage in futures markets: Evidence from the Sydney Futures Exchange, *Journal of Futures Markets* 25, 1129–1146.
Glosten, L. and P. Milgrom, 1985, Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders, *Journal of Financial Economics* 13, 71-100.
Jones, C. and M. Lipson, 2001, Sixteenths: Direct evidence on institutional trading costs, *Journal of Financial Economics* 59, 253-278.
Kraus, A. and H. Stoll, 1972, Price impacts of block trading on the New York Stock Exchange, *Journal of Finance* 27, 569–588.
Mansanet-Bataller, M., A. Tornero, and E. Mico, 2006, CO2 Prices, Energy and Weather, *Working Paper,* University of Valencia.
Mansanet-Bataller, M. and A. Pardo, 2007, The Effects of National Allocation Plans on Carbon Markets, *Working Paper,* University of Valencia.
Milunovich, G. and Joyeux, R., 2007, Market Efficiency and Price Discovery in the EU Carbon Futures Market, *Working Paper,* Macquarie University.
Sijm, J., K. Neuhoff, and Y. Chen, 2006, CO2 cost pass-through and windfall profits in the power sector, *Climate Policy* 6, 49-72.

Appendix 1: Contract specifications for ECX CFI futures

Table A1 below reports the contract specifications for ECX CFI futures.

<INSERT TABLE A1 HERE>

Appendix 2: National Allocation Plans

Table A2 below reports Phase II National Allocation Plans for each Member State of the European Union.

<INSERT TABLE A2 HERE>

Table I
Descriptive statistics

This table reports descriptive statistics for all ECX CFI futures contracts in the sample. Contracts are listed according to their yearly expiry date and contracts with a monthly expiry are grouped together. *Trade Volume* is the total number of contracts per trade, where each contract represents 1,000 tonnes of CO_2. 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	13.078	20.698	1	5	9	10	10	20	375	1,327
December 2006	11.736	15.15	1	4	5	10	10	20	600	16,822
December 2007	12.966	17.462	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	10.365	1	1	2	5	10	17	129	3,705
December 2010	7.85	10.568	1	1	1	5	10	20	194	1,497
December 2011	10.36	14.269	1	1	5	5	10	25	175	450
December 2012	14.021	19.921	1	1	5	10	15	40	200	654
December 2013	10.000	0.000	10	10	10	10	10	10	10	4
All monthly contracts	9.255	16.715	1	1	2	5	10	20	200	1,174
Total Sample	*8.580*	*11.490*	*1*	*1*	*2*	*5*	*10*	*20*	*600*	*116,559*

Table II
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 CO2. The percentage of total quarterly on-market volume is reported in parentheses.

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

Table III
Trading activity and price volatility: December 2008 futures

This table reports 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 over the quarter. 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	17.292	0.000	0.000	0.05	0.05
Mar Q 2006	43.077	2.600	16.794	5.194	0.009	0.05	0.05
Jun Q 2006	239.656	14.344	15.895	26.750	0.077	0.05	0.05
Sep Q 2006	245.508	13.877	15.603	6.571	0.016	0.05	0.05
Dec Q 2006	319.125	34.563	9.429	13.560	0.029	0.05	0.05
Mar Q 2007	692.828	71.906	9.328	14.080	0.035	0.05	0.05
Jun Q 2007	1115.594	137.406	7.989	23.495	0.044	0.01	0.05
Sep Q 2007	1510.585	171.323	8.725	14.421	0.026	0.01	0.05
Dec Q 2007	1107.231	140.015	7.940	10.832	0.017	0.01	0.05
Mar Q 2008	2095.556	369.254	5.802	15.682	0.027	0.01	0.05
Jun Q 2008	2570.833	398.778	6.827	12.466	0.018	0.01	0.05

Table IV
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 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 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 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	11.000	5.500	10.000	14.333	0.05	0.05
Mar Q 2006	0.390	7.798	3.899	11.694	11.290	0.05	0.05
Jun Q 2006	0.652	13.037	6.530	15.667	10.664	0.05	0.05
Sep Q 2006	0.197	3.937	1.967	9.649	10.242	0.05	0.05
Dec Q 2006	0.129	2.578	1.288	10.895	12.390	0.05	0.05
Mar Q 2007	0.099	1.970	0.985	12.486	11.593	0.05	0.05
Jun Q 2007	0.083	1.654	0.827	10.918	11.913	0.01	0.05
Sep Q 2007	0.064	1.277	0.638	11.588	12.024	0.01	0.05
Dec Q 2007	0.057	1.135	0.567	10.404	10.050	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

Table V
Total, temporary and permanent price effects: December 2008 futures

This table reports total, temporary, and permanent price effects for ECX CFI futures expiring in December 2008. Panel A reports results using a 5-trade benchmark and Panel B reports results using a 10-trade benchmark. *Total* captures the total price effect associated with the trade and is the difference between the volume-weighted average price (VWAP) of the trade and the pre-trade benchmark price. *Temporary* measures the temporary price effect (price reversal) associated with the trade and is the difference between the post-trade benchmark and the VWAP of the trade. *Permanent* measures the permanent price effect (price continuation) and is the difference between the post-trade benchmark and the pre-trade benchmark. *Total*, *temporary*, and *permanent* are scaled by the minimum tick.

	Total		Temporary		Permanent	
Trade size group	Buy	Sell	Buy	Sell	Buy	Sell
Panel A: 5-trade benchmark						
Small (<5)	0.466	0.587	-0.064	-0.034	0.402	0.553
	(56.10)	(58.42)	(-7.27)	(-3.46)	(34.57)	(39.10)
Medium (5-15)	0.616	0.828	0.012	0.062	0.629	0.890
	(46.57)	(33.33)	(0.78)	(3.00)	(29.22)	(27.04)
Large (>15)	0.744	0.930	0.038	0.036	0.783	0.966
	(22.39)	(18.20)	(1.28)	(0.98)	(19.65)	(15.04)
Panel B: 10-trade benchmark						
Small (<5)	0.571	0.739	-0.067	-0.006	0.505	0.733
	(48.43)	(55.83)	(-5.52)	(-0.46)	(30.95)	(41.65)
Medium (5-15)	0.779	1.009	0.000	0.017	0.779	1.026
	(40.86)	(33.34)	(0.01)	(0.71)	(29.16)	(28.54)
Large (>15)	0.873	1.066	0.047	0.124	0.919	1.190
	(24.64)	(21.27)	(1.39)	(2.82)	(18.54)	(18.47)

Table A1
Contract Specifications for ECX CFI futures

Table A1 below reports the contract specifications for ECX CFI futures.

Contract	ECX CFI Futures
Unit of trading	1 lot = 1,000 CO2 EU Allowances (EUAs) 1 EUA = entitlement to emit 1 tonne of CO2 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 and the Handbook of World Stock, Derivative & Commodity Exchanges 2007

*The tick size decreased from €0.05 to €0.01 on 27 March, 2007.

Table A2
Phase II National Allocation Plans for EU Member States

Table A2 below report 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 put 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 CDM and JI credits into the scheme as both a percentage and in $MtCO_2$.

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*	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%	n/a	
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*	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	2,298.50	2,122.20	2,325.30	2,080.90	-10.50%		278.7

Source: Deutsche Bank and the European Commission

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