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Carbon Credits: Who is the Leader of the Pack?

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ABSTRACT: We provide the first intraday analysis on the contribution to price discovery of two emissions carbon credits: European Union Allowances (EUAs) and Certified Emission Reductions (CERs). We find that EUAs lead price discovery but CERs play a growing role and, therefore, should not be ignored.

Keywords: European Union Allowances; Certified Emission Reductions; co-integration, price-discovery; high frequency data; intraday analysis.
JEL Classifications: G10

1. Introduction

The EU Emission Trading Mechanism (EU ETS) handles the trading of greenhouse gas emission allowances among EU members. The EU ETS is the largest emission-trading scheme in the world, not only in terms of allowances distributed but also in terms of energy intensive installations covered (see Mansanet-Bataller and Pardo, 2008). Currently, each Member State fixes, through a National Allocation Plan (NAP) that must be approved by the European Commission, an emission target. According to the NAPs, the European Commission allocates European Union Allowances (EUAs) to each country to cover their emission targets. EU Member States then distribute the EUAs among the companies covered by the 2003/87/EC Directive. Each EUA allows for the emission of one tonne of CO_2-equivalent and they can be traded through the EU ETS. The trading of EUAs is fragmented through different organized electronic markets. The most important spot market is BlueNext (Paris), while the most important derivative market is by far the European Climate Exchange (ECX, London).

Some aspects of the EU ETS have determined its development. The EU ETS has been implemented in several Phases. "Phase I" (from 2005 to 2007) was a pilot/learning phase negatively marked by an involuntary excess of allocated EUAs, which inevitably lead to the collapse in their prices that fell close to zero by the end of the phase. "Phase II" (from 2008 to 2012) coincides with the Kyoto Protocol accomplishment period. "Phase III" will last from 2013 to 2020.[1]

In addition, the 2004/101/EC Directive of the European Parliament (the “Linking Directive") allows EU-members to use Kyoto certificates from the so-called "project-based flexible mechanisms" to cover their domestic greenhouse gas emissions. One of these flexible mechanisms is the Clean Development Mechanism (CDM). By developing an emissions-reduction project in a developing country, the EU country generates credits known as Certified Emissions Reductions (CERs) that can be used to meet its emissions targets under the Kyoto protocol. Each CER represents a successful

[1] See further details at http://www.environment-agency.gov.uk/business/topics/pollution/113457.aspx, last accessed on 6/7/2011.

emission reduction of one tonne of carbon dioxide.[2] Generally speaking, the inclusion of CERs into the EU ETS had three main objectives: (i) to increase overall liquidity in the system; (ii) to reduce the abatement costs of the energy intensive installations covered; and (iii) to contribute to sustainable development in developing countries. CERs can be imported into the EU ETS for compliance purposes and are fully fungible with European Union Allowances (EUAs) up to a predetermined limit, which varies between countries (see Trotignon, 2010).

Since 2008, CERs and EUAs have been simultaneously traded through electronic linked markets, raising the interest of researchers in analyzing the relative contribution of CER and EUA markets to price discovery. On one hand, Mansanet-Bataller et al. (2011) for the period March 2007 to March 2009, and Chevallier (2010) for the period March 2007 to January 2010, find that EUA prices and CER prices have a significant causal influence on each other, but EUA futures markets lead price discovery. On the other hand, Nazifi (2010) concludes that EUA prices and CER prices between May 2007 and September 2008 do not have a common long-run component. She also observes that in the short-run, CER prices do not cause EUA prices, while EUAs do cause CER prices. Similarly, Mizrach (2012) reports that between July 2007 and December 2008 the null of no-common-factors between EUA prices and CER prices cannot be rejected. Despite these studies sharing both sample periods and approaches (co-integration techniques), their results about price leadership in the EU ETS are mutually inconsistent.

A potential limitation of prior studies is that they use exclusively daily data on EUAs and CERs. With a daily time resolution, it is not possible to detect error-correction patterns that take place at higher trading frequencies. As Harris et al. (1995, p. 567) point out, “we must guard against observation intervals so long that error correction takes place within rather than between [them]”. In this paper, we use a unique database of high-frequency trading data from the most active futures market contracts on EUAs and CERs, the ICE ECX market, to study the relative contribution of each entitlement to the price discovery process. We show that EUAs lead price discovery, but that CERs have a growing importance and may come to play a major role in the carbon market.

The remainder of this paper is structured as follows: in section 2 we describe the part played by CERs in the European carbon market and we refer briefly to the theoretical aspects underpinning the link between EUAs and CERs. In section 3 we provide details about the database and the methodology used in our study. In section 4 we summarize our main empirical findings and, finally, in section 5 we conclude.

2. The Linking Directive and CERs

The 2004/101/EC Directive of the European Parliament permits Member States to use CERs to cover their domestic greenhouse gas emissions. CERs are fully fungible with EUAs up to a specific percentage limit to be decided by each EU Member. Trotignon (2010) reports that this limit varies between 0% and 20%, depending on countries and sectors, the average being about 13.5% (1,420Mt for the period 2008-2012).[3]

Theoretically speaking, the substitutability between EUAs and CERs should lead to the fulfillment of the Law of One Price: assets with the same expected future payoffs must have the same price today. However, from the time that CERs began to trade in 2008, EUAs have been quoted above CERs both in the spot and the futures markets. Specifically, let $EUA_t(T,T')$ and $CER_t(T,T')$ be the price of an EUA futures contract and a CER futures contract, respectively, at period t, for phase T' and maturity T, with $t \leq T \leq T'$. In practice, $EUA_t(T,T') - CER_t(T,T') > 0$.[4] According to Mansanet-Bataller et

[2] This emission reduction must be certified by the CDM Executive Board of the United Nations' Framework Convention on Climate Change (UNFCCC).

[3] CERs generated by nuclear facilities, however, cannot be used for compliance purposes, and neither can those obtained from land use, land use change, and forestry activities.

[4] As long as this divergence in prices compensates for transaction costs (such as bid-ask spreads and fees), it could be easily exploited by those polluters that have EUAs by selling EUAs and buying CERs (until the limit of CERs that can be surrendered is reached). However, Trotignon (2010) reports that in 2008 and 2009, polluters did not surrender as many CERs as they could, meaning that either they are intentionally ignoring this arbitrage opportunity or they are not paying sufficient attention to the possibility of exploiting it.

al. (2011), there are two factors that, when put together, may explain the persistence of the positive spread between EUA and CER prices. Firstly, in order to benefit from this arbitrage opportunity, market agents need to buy CERs and exchange them for EUAs from their own registry. Secondly, there is a limit that each country has imposed regarding the use of CERs for compliance purposes. Therefore, the arbitrage opportunity of buying CERs and selling EUAs is limited in quantity and over time, and it will be greatly determined by uncertainties about the future demand and supply of both EUAs and CERs. Thus, the recent international economic crisis augments the uncertainty about the amount of EUAs that large emitters will finally need to cover their emissions during Phase II. Moreover, the lack of a clear regulatory regime for CERs post 2012, and the likely exclusion or restriction in Phase III of CERs generated by certain types of projects, increase the risk about the future supply of CERs.[5] In the case of an above-expected supply of CERs, the demand for EUAs would decrease and, consequently, EUA prices would also decrease. This is why some carbon traders point to CERs as the main reason for weakening EUA prices. However, other traders think that a possible declining demand for EUAs due to the crisis, and the consequent fall in EUA prices would lead to a decrease in CER prices.

Since 2008, trading activity has increased for both EUA and CER futures contracts. Nevertheless, this increase has not been distributed evenly. December 2008 CER futures contract exhibited a market share of 12.51%, while December 2009 and 2010 CER futures contracts reported market shares of 13.72% and 14.02%, respectively. This trend shows that CER volume has been increasing more than EUA volume.

Additionally, we have calculated the Spearman's correlation coefficients, between EUA and CER futures contracts for the logarithm of the number of daily transactions. We find a strong positive correlation between EUAs and CERs that has been increasing over time, given that the coefficients are 43.41%, 73.09% and 77.82%, for December 2008, 2009 and 2010 futures contracts, respectively.

3. Data and Methodology

Our database consists of high frequency trade data from the ECX futures market. We analyze six futures contracts with maturities in December 2008, 2009 and 2010, three with EUAs as the underlying asset and three with CERs as the underlying asset. For every trade, the database reports the time stamp (GMT), the trade price in Euros, the maturity of the contract, the trade size and the trade sign (i.e., whether it is buyer-initiated or seller-initiated). In Table I, we report some summary statistics and relevant facts about the chosen contracts.

Table 1 shows that futures on EUAs have been traded in ECX since April 2005, but futures on CERs have been traded only since March 2008. Therefore, we only consider data from March 2008 on to perform our price-discovery analysis. Table I also shows that the median price of the EUA futures contract is higher than the median price of the CER futures contract in all cases, illustrating the positive spread highlighted in Section 2 of the paper. Notice, however, that this spread has diminished over time, from 5.60€ to 2.20€ per tonne. Regarding trading frequency, the EUA futures contract is traded on average once every two minutes, whereas the CER futures contract is traded on average once every 15 minutes. To minimize a potential problem of non-synchronicity, our study is implemented using 15-minute time intervals.[6] We split each trading session into 15-minute intervals. For each time interval, we take the last trade price available. Overnight returns are excluded from the analysis.

[5] From 2013 on, the use of CERs from projects involving trifluoromethane (HFC-23) and nitrous oxide (N_2O) from adipic acid production will be limited because of the exceptionally high rates of chlorodifluoromethane (HCFC-22) derived from the destruction of HFC-23. Since these projects represent about 50% of the total supply of CERs, the effect over the total supply may be dramatic. For more details, please visit http://ec.europa.eu/clima/news/news_2010_11_en.htm.

[6] Trading frequency in the spot ECX market is much lower than in the futures market. On average, EUAs are traded once every 15 minutes while CERs are traded once every 176 minutes. Because of the low trading frequency of CERs in the spot market, we carry out our analysis using exclusively derivatives data.

Table 1. Futures contracts facts and statistics

This table reports some facts and summary statistics about the six futures contracts analyzed in this paper, three of them with EUAs as the underlying asset, and three with CERs as the underlying asset. Maturities are December 2008, 2009 and 2010. One lot stands for 1,000 CO_2 EU allowances.

	EUA Futures Contracts			CER Futures Contracts		
Maturity	December 2008	December 2009	December 2010	December 2008	December 2009	December 2010
Number of transactions	238,647	312,130	330,390	8,253	19,107	26,509
Price mean	21.93	13.85	14.61	18.55	13.06	12.99
Price std. deviation	3.38	2.77	1.61	2.46	3.00	2.23
Maximum price	33.70	32.50	32.22	26.80	26.20	25.25
Median price	22.25	13.73	14.70	19.20	12.45	12.49
Minimum price	10.75	7.70	8.25	12.65	7.15	7.35
Volume (in lots)	2,188,980	3,057,609	3,598,073	162,478	469,491	578,943
Average volume per transaction (in lots)	9.1725	9.7959	10.8904	19.6871	24.5717	21.8395
Maximum volume (in lots)	4,000	4,000	3,000	2,000	4,500	1,825
Minimum volume (in lots)	1	1	1	1	1	1
First transaction: Day	6/17/05	10/12/05	1/26/06	3/14/08	3/14/08	3/14/08
First transaction: Time	4:04:00 PM	1:20:00 PM	5:05:00 PM	7:00:00 AM	1:37:03 PM	1:37:49 PM
Last transaction: Day	12/15/08	12/14/09	12/20/10	12/15/08	12/14/09	12/20/10
Last transaction: Time	4:41:34 PM	5:17:00 PM	4:59:00 PM	4:59:54 PM	4:56:54 PM	4:59:17 PM
First trading day	4/22/05	4/22/05	4/22/05	3/14/08	3/14/08	3/14/08
Last trading day	12/15/08	12/14/09	12/20/10	12/15/08	12/14/09	12/20/10
Number of trading days	934	1,188	1,447	194	448	707
Transactions per day	255.5107	262.7357	228.3276	42.5412	42.6496	37.4950
Transaction per minute	0.4347	0.4454	0.3862	0.0709	0.0712	0.0627
Average minutes between transactions (ex overnight)	2.3002	2.2450	2.5895	14.1040	14.0367	15.9568
Number of price changes	134,265	135,350	133,535	8,060	18,664	22,109
Number of price changes per day	143.7527	113.9310	92.2840	41.5464	41.6607	31.2716

In Figure 1, we plot the time-series of prices for the futures contracts with two different time resolutions: prices every 15 minutes (upper panels) and daily (settlement) prices (bottom panels). The latter is the time resolution in previous studies about price discovery in the European carbon market. Notice that while settlement price plots show the previously reported persistent positive spread between EUA and CER futures prices, the intraday plots reveal that EUA and CER prices converge in specific moments along the trading session.

According to Engle and Granger (1987), the most efficient parameterization of a vector of co-integrated variables is a Vector Error Correction Model (VECM). In our case, a standard error-correction representation for the EUA and CER futures prices would be,

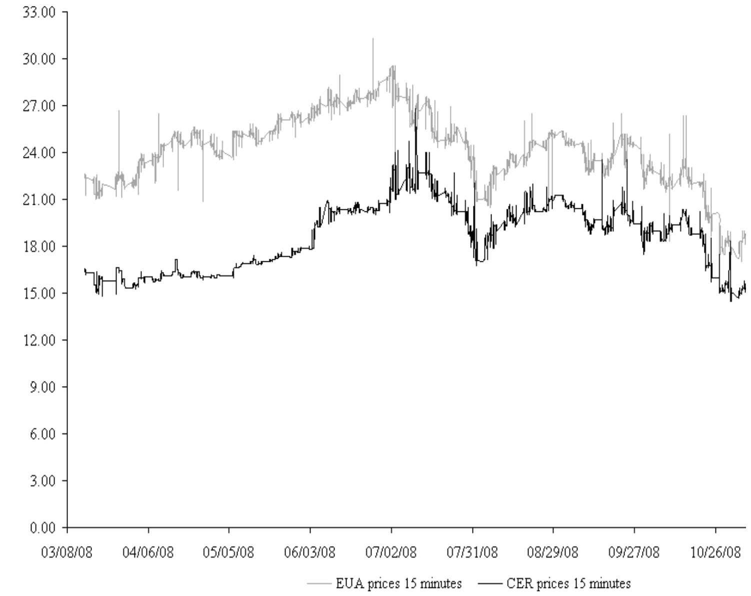
$$\begin{aligned}\Delta EUA_t &= \delta_{EUA} Z_{t-1} + \mu^{EUA} + \sum_{i=1}^{k} \beta_i^{EUA} \Delta EUA_{t-i} + \sum_{i=1}^{k} \gamma_i^{EUA} \Delta CER_{t-i} + \varepsilon_t^{EUA} \\ \Delta CER_t &= \delta_{CER} Z_{t-1} + \mu^{CER} + \sum_{i=1}^{k} \beta_i^{CER} \Delta EUA_{t-i} + \sum_{i=1}^{k} \gamma_i^{CER} \Delta CER_{t-i} + \varepsilon_t^{CER}\end{aligned} \quad (1)$$

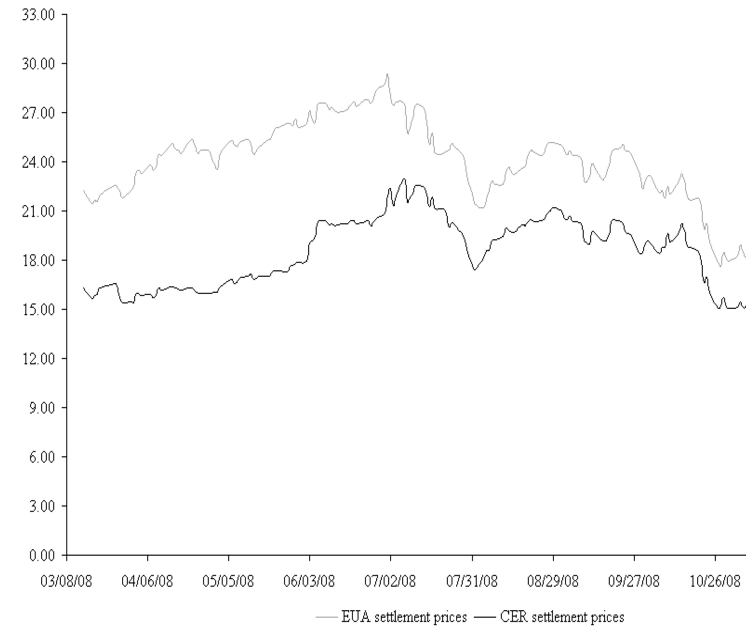
where $Z_{t-1} = EUA_{t-1} - \alpha CER_{t-1}$ is the error-correction term and $(1, \alpha)$ is the normalized error-correction vector. Z_{t-1} captures deviations from the long-run equilibrium relationship between EUA and CER futures prices. Deviations from this equilibrium are possible, but they cannot persist over time; that is, Z_{t-1} is a co-variance stationary process. Since we have only two potentially co-integrated time series in equation (1), we can have at most one co-integrating vector and, hence, a unique common stochastic trend governing the long-run relationship between EUAs and CERs (Stock and Watson, 1988). The $\delta = (\delta_{EUA}, \delta_{CER})$ vector contains the error-correction coefficients while δ_j measures the response of the market j to a deviation from the other market's price. If both δ_{EUA} and δ_{CER} were statistically significant, we would be facing a two-way price discovery process (e.g., Harris et al., 1995). Because of the definition of Z_{t-1}, we expect $\delta_{EUA} \leq 0$ and $\delta_{CER} \geq 0$. Everything else being equal, if the deviation from the equilibrium turns out to be positive (Z_{t-1}>0), CER prices are expected to rise and EUA prices are expected to fall in order to restore the long-run equilibrium relationship. Using the terminology introduced by Garbade and Silber (1979), if the EUA futures market dominates price discovery and the CER futures market is its "satellite", we should find that δ_{EUA} is not statistically different from zero, while δ_{CER} is statistically larger than zero.

Figure I. Evolution of intraday and daily prices

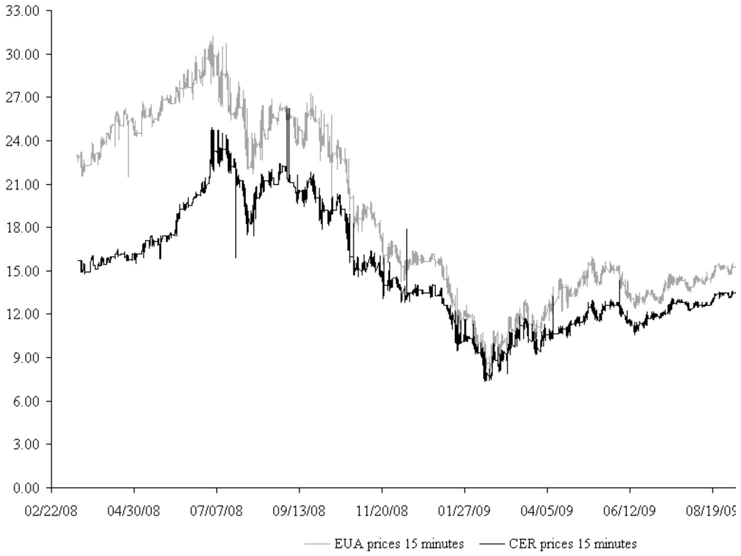
Panels A, B and C exhibit the prices for 2008, 2009 and 2010 EUA and CER futures contracts, respectively. In each panel, the figure on the left side exhibits the historical intraday prices of the last occurring transaction in intervals of fifteen minutes. Similarly, the figure on the right side shows the historical daily settlement. 2008 EUA and CER futures contracts refers to the futures contracts maturing on December 15, 2008; 2009 EUA and CER Futures Contracts refers to the futures contracts maturing on December 14, 2009; and 2010 EUA and CER Futures Contracts refers to the futures contracts maturing on December 20, 2010.

Panel A. 2008 EUA and CER futures contracts

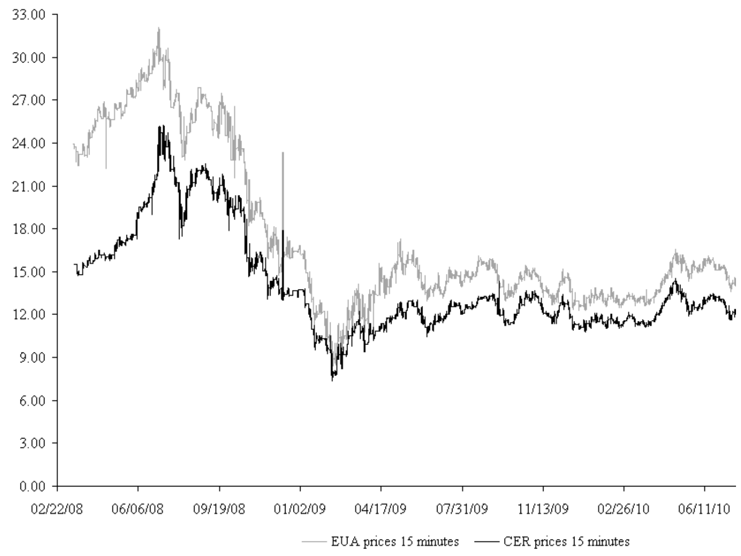


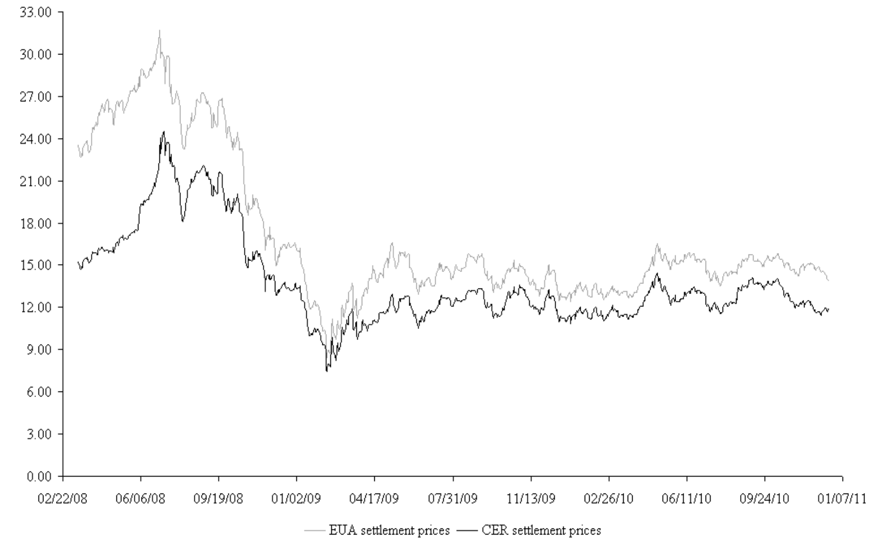


Panel B. 2009 EUA and CER futures contracts



Panel C. 2010 EUA and CER futures contracts





Model (1) permits EUA and CER returns to respond to deviations from the long-run equilibrium relationship, but also allows lagged adjustments of prices to shocks in any of the two futures markets due to market frictions. The remaining terms in the RHS of equation (1), where μ^{EUA} and μ^{CER} are constants, capture these short-term dynamics between EUAs and CERs. The autoregressive polynomials in the RHS of (1) are assumed to be weak stationary, which means that the β_j and γ_j coefficients converge to zero as j increases. Thus, any (informative) shock affecting the long-run common stochastic factor between EUA and CER futures prices will be permanently embedded into prices, while the effect of any uninformative shock will vanish over time and will not remain in the memory of the process. The lag length k is to be determined using the Schwarz Information Criterion.

The VEC representation (1) is only valid if (a) EUA and CER futures prices are integrated of the same order, presumably of order 1, and (b) they are co-integrated, that is, we can find a linear combination of the two prices given by the co-integrating vector $(1,\alpha)$, which is stationary. We test for the existence of unit roots in the time series by using the Kwiatkowski et al. (1992) test. We confirm that all the time series of futures prices for EUAs and CERs have a unit root.[7] We also test for co-integration using the very well-known methodology proposed by Johansen (1988 and 1992) and Johansen and Juselius (1990).[8] Both the trace statistic and the maximum eigenvalue test suggest that there is one cointegration vector.[9]

In Table 2 (Panel A), we provide maximum likelihood ratio tests on the statistical significance of the coefficients of the co-integrating vector.[10] We report that, for all maturities, EUA and CER futures prices enter in a statistically significant way into the co-integration relationship, confirming the existence of a significant long-run equilibrium relationship involving EUA and CER futures prices. Our findings therefore disagree with the daily-data-based analyses of Nafizi (2010) and Mizrach (2012).

As discussed in Section 2, the positive spread between EUA and CER prices has progressively decreased over time, suggesting a potential deterministic component in the co-integration relationship between EUA and CER futures prices. Panel B of Table 2 reports our findings from testing the null that there is no deterministic trend in the co-integrating relationship. The null of no deterministic trend

[7] Following other methodologies, Joyeux and Milunovich (2010) determined that Phase I EUAs were also integrated of order 1.

[8] Following Kwiatkowski et al. (1992, p.159), “It is a well-established empirical fact that standard unit root tests fail to reject the null hypothesis of a unit root for many economic time series”. To avoid this fact, Kwiatkowski et al. (1992) provides a straightforward test of the null hypothesis of stationarity against the alternative of a unit root.

[9] These results are available upon request from the authors.

[10] For details on this statistical test, see Johansen (1992).

is rejected at the 1% level of statistical significance in all cases, corroborating the progressive convergence between EUA and CER futures prices.

Table 2. Statistical test on the long-run equilibrium relationship

In Panel A, we report the output of a test on the null hypothesis that the futures price *j* does not enter into the co-integration relationship. Namely, the null hypothesis is H_0: $B(i,j)=0$, where $B(i,j)$ is the *j*th coefficient of the *i*th co-integrating vector, where $i=\{2008,2009,2010\}$, and $j=\{EUA,CER\}$. The test statistic is distributed as a Chi-square random variable with 1 degree of freedom. Panel B reports the coefficient and its standard error estimated for the *Trend* variable in each co-integrating vector.

Panel A	EUA and CER 2008		EUA and CER 2009		EUA and CER 2010	
Variable	χ^2	p-value	χ^2	p-value	χ^2	p-value
EUA_{t-1}	32.2116	0.0000	174.4765	0.0000	181.1691	0.0000
CER_{t-1}	31.0130	0.0000	186.3839	0.0000	183.6680	0.0000
Panel B	EUA and CER 2008		EUA and CER 2009		EUA and CER 2010	
Variable	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Trend	4.00E-05	3.2E-06	1.36E-05	1.2E-06	4.16E-06	7.4E-07

4. Empirical Findings

In Table 3 (Panel A), we report the estimated coefficients of the VEC model in equation (1). For all maturities, the error-correction coefficients δ_{EUA} and δ_{CER} are both statistically significant and with the expected sign. Hence, Table 3 reveals a two-way price discovery process, with both EUA and CER futures prices error-correcting to deviations from the other market prices.

Table 3. Vector error-correction models

In Panel A, we report the estimated coefficients of a VEC model for the prices (in logs) of the futures contracts on EUAs and the futures contracts on CERs. The model is estimated for three different maturities: December 2008, 2009, and 2010. The optimal number of lags is determined by the Schwartz Information Criterion. Z_{t-1} stands for the error-correction term. In Panel B, we report the contributions of each market to price discovery as measured by the common factor weights of Gonzalo and Granger's (1995) methodology and the percentage which represents the volume for both EUA and CER contracts, with respect to the total, for each maturity. (*) means statistically significant at the 1% level.

Panel A	**EUA and CER 2008**		**EUA and CER 2009**		**EUA and CER 2010**	
Variable	ΔEUA	ΔCER	ΔEUA	ΔCER	ΔEUA	ΔCER
Z_{t-1}	-0.0154*	0.0162*	-0.0098*	0.0213*	-0.0071*	0.0079*
Intercept	-8.7E-05	-3.9E-05	-6.0E-06	-2.3E-05	-4.9E-05	-2.3E-05
ΔEUA_{t-1}	-0.7377*	0.0141	-0.4592*	-0.0162	-0.2364*	0.0225*
ΔEUA_{t-2}	-0.5431*	0.0326	-0.2570*	0.0255*	-	-
ΔEUA_{t-3}	-0.4135*	0.0264	-	-	-	-
ΔEUA_{t-4}	-0.3034*	0.0186	-	-	-	-
ΔEUA_{t-5}	-0.1144*	0.0148	-	-	-	-
ΔCER_{t-1}	0.0291	-0.3410*	0.0017	-0.2835*	0.0595*	-0.1203*
ΔCER_{t-2}	0.0384	-0.2193*	0.0114	-0.1606*	-	-
ΔCER_{t-3}	0.0243	-0.1870*	-	-	-	-
ΔCER_{t-4}	0.0043	-0.1489*	-	-	-	-
ΔCER_{t-5}	-0.0148	-0.1348*	-	-	-	-
Panel B	**ΔEUA**	**ΔCER**	**ΔEUA**	**ΔCER**	**ΔEUA**	**ΔCER**
ω_j	0.5128	0.4872	0.6852	0.3148	0.5278	0.4722
% Volume	0.8749	0.1251	0.8628	0.1372	0.8598	0.1402

We find that $|\delta_{EUA}|<|\delta_{CER}|$ in all cases, the difference being particularly large for the December 2009 futures contracts. Therefore, the CER futures price is more responsive to deviations from the EUA futures price than the other way around. A formal measure of leadership in price discovery can be obtained using the methodology proposed by Gonzalo and Granger (1995). The contribution of each market to the formation of the true value of the asset (common efficient price) is given by the orthogonal vector to the vector of error-correction coefficients (δ). In our case,

$$\omega_{EUA}=\frac{\delta^{CER}}{\delta^{CER}-\delta^{EUA}}, \quad \omega_{CER}=\frac{-\delta^{EUA}}{\delta^{CER}-\delta^{EUA}}. \tag{2}$$

Panel B of Table 3 reports the estimated contributions. In general, the contribution of the EUA futures market to price discovery is only slightly superior to that of the CER futures market for the December 2008 and December 2010 maturities and greatly superior for the December 2009 maturity. Therefore, even though our findings suggest that the EUA market dominates price discovery in the European carbon market, the CER futures market plays a very important role. This conclusion is reinforced if we compare the estimated contributions to price discovery with the actual shares in trading volume. The EUA market share in terms of volume traded is between 86% and 87.5% depending on the contract maturity. Its contribution to price discovery, however, varies between 51% and 68.5%. In contrast, the CER market share of total volume is between 12.5% and 14%, whereas its contribution to price discovery varies between 31.5% and 48.7%. Therefore, we must conclude that the contribution of the CER market to price discovery is disproportionately large, suggesting a significant concentration of information-motivated trading in the CER market.

Regarding short-run dynamics, Table 4 reveals a two-way short-term Granger causality. We perform formal short-run causality tests. Namely, for each equation in the VECM, we test whether the lagged coefficients of the other market's returns are jointly statistically different from zero. Table IV summarizes our findings. For the December 2008 futures contracts, the null of no causality cannot be rejected (at the 1% level). This picture changes for the December 2009 futures contracts. The null of no causality cannot be rejected for the EUA price equation, but it is rejected for the CER price equation, revealing a predominant role of the EUA market over the CER market in the short-run. Finally, in the 2010 case, we find evidence of a two-way short-run causality. Therefore, our findings suggest that the level of short-run integration of the EUA and CER markets has increased through time.

Table 4. Short-run causality tests

In this table, we report statistical tests for short-run causality between the prices of EUA futures contracts and CER futures contracts using the estimated coefficients of a VEC model. The table displays the chi-square statistic for the null hypothesis. All the coefficients of the lagged returns for the other futures contracts are jointly statistically insignificant.

		Endogenous variables					
		2008 Futures Contract		2009 Futures Contract		2010 Futures Contract	
Null Hypothesis		ΔEUA_t	ΔCER_t	ΔEUA_t	ΔCER_t	ΔEUA_t	ΔCER_t
$H_0:\beta_1=\ldots=\beta_k=0$	X^2	-	6.5820	-	19.7714	-	23.5948
	p-value	-	0.2536	-	0.0001	-	0.0000
$H_0:\gamma_1=\ldots=\gamma_k=0$	X^2	10.7552	-	2.7351	-	58.1116	-
	p-value	0.0565	-	0.2547	-	0.0000	-

For robustness purposes, we have repeated all the previous empirical analyses with alternative time resolutions, namely, 20-minute and 30-minute time intervals. We conclude that our main conclusions do not depend on the time resolution of our analysis.[11]

[11] These additional findings are available upon request.

5. Conclusions

In this paper, we analyze price leadership between the two most important carbon credits in the EU ETS: EUAs and CERs. Prior empirical studies on this issue use daily data and report mixed findings. Instead, we use high frequency transaction data in an attempt to resolve the existing controversy on this issue. Our findings show that there is a long-run equilibrium relationship between both price permits. Although EUAs dominate price discovery, the contribution of CERs is disproportionately large compared with their share in trading volume. Our findings suggest an overly large concentration of information-motivated trading in the CER futures market.

Future research should go more deeply into the motives of this apparent dominance of information-motivated trading in the CER market. Moreover, given the remarkable role the CER market plays in price discovery, future regulatory measures should consider simultaneous and coordinated actions in both the EUA and CER markets.

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