Carbon Finance and Its Pricing Mechanism: an Evidence from EU ETS*

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Abstract: The carbon emission will be the most experienced environmental financial innovation in globe. This paper examines the future emission linkages between the EUA and CER in terms of volatility and price spillovers. By using a bi-variable asymmetric GARCH-BEKK model, we find evidence of returns and volatility uni-directional spillovers from the CER to EUA. However, as the estimated time-varying conditional correlation indicates high interactions between the instruments, the project-based market is strongly linked to the allowance-based markets.
Keywords: Multivariate GARCH, Carbon emission, EU ETS

1 Introduction

Climate change is a serious crisis in sustainable development of human being, it is now generally accepted amongst scientists and politicians that the increasing concentration of greenhouse gases (GHGs) in the atmosphere over the past century is linked to human activities. The carbon emissions trading market (carbon market) is the most effective solution to mitigate climate change. The international community has signed the United Nations Framework Convention on Climate Change and the Kyoto Protocol to control carbon dioxide (CO_2) emissions in 1992 and 1998, respectively. However, until 2005, European Union emissions trading Scheme (EU ETS) hasn't formally entered into operation in the EU-wide. Carbon market is strictly based solely on international agreements, thus, insufficient international cooperation leads to fragmented carbon markets and each sub-market price fluctuations independent. The pricing mechanism of global carbon market is not transparent and unintegrated, which has a negative impact on the global economic transition process to low-carbon, ultimately, away from the target of mitigation of climate change.

The EU ETS represents a new paradigm, since environmental policy has historically been a command-and-control type regulation where companies have to strictly comply with emission limits. Emission trading is a regulatory program that gives firms the flexibilities to select effective solutions of cost to achieve established environmental goals, which are required to reduce worldwide greenhouse gas emissions by a collective average of 5% below 1990 levels of member countries.

After five consecutive years of robust growth, the total value of the global carbon market stalled at $142 billion. As other segments decline, the dominance of the EU ETS market with the secondary CDM becomes more pronounced than ever, which accounts for 97 percent of global carbon market value in 2010, dwarfing the remaining segments of the market(World Bank, 2011).

The paper makes two further major contributions. Firstly, it empirically investigates the behavior of European Union Allowance (EUA) and Certified Emission Reductions (CER) future prices of the EU ETS by using multivariate GARCH model. Previous research on the carbon markets has only focused primarily on the EUA alone by using univariate GARCH model by contrast. Secondly, it extends the relevant environmental economics literature by using recent carbon future data to avoid emission allowance banking prohibition for financial markets. The timing is particularly good since it starts from 2008 onwards. It avoids the immaturity of the EU ETS and to the restrictions imposed on short-selling and on banking in the first preliminary phase lasted from 2005 to 2007. By the end of 2007, the EU Commission started reviewing the function of the ETS in order to propose potential improvements for the post-2012 period. The second veritable phase covers the years from 2008 to 2012, coinciding with Kyoto's first commitment period.

The remainder of the paper is organized as follows: Section 2 examines the features of the two futures under study. On the basis of the inspections in Section 2, Section 3 presents the methodology to be used. Section 4 reports the empirical results and discusses their implications. Section 5 concludes.

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2 Carbon Market Mechanism and Instruments

2.1The carbon market and emission allowances

According to World Bank classification, the carbon market is divided into allowance-based and project-based markets. The former includes EU ETS, New South Wales ETS, Chicago Climate Exchange, etc., which are under international mechanism. The latter includes primary CDM (Clean Development Mechanism), secondary CDM, JI (Join Implement) and other compliance and voluntary markets, of which secondary CDM is the largest in term of value. The carbon credit achieved from CDM is CER; JI does ERU (Emission Reduction Unit).

The EU ETS establishes the largest multi-country and multi-sector GHG market in the world with mandatory constraints. It covers 12,000 installations in 30 countries responsible for nearly half of the EU's CO_2 emissions. The EU ETS requires a cap-and-trade program whereby the EUA giving rights to emit a tonne of CO_2 becomes a tradable commodity. Because total assigned EUA are less than real emissions, while real abatement cost is expensive, the facility is allowed to purchase other carbon reduction to offset its compliance under Kyoto protocol. Thus, a new commodity is produced in the form of CER by conducting project by Clean Development Mechanism. Each EUA or CER is considered equivalent on one tone of carbon dioxide emissions.

Under the Kyoto Protocol, the EU has committed to reduce GHG emissions by 8% compared to the 1990 level in the years 2008–2012. The EU ETS specify three phrases: Phrase I (2005-2007), Phrase Ⅱ (2008-2012) and Phrase Ⅲ (2013-2020).The system regulates an annual allocation of allowances. The committed firms must surrender the allowances to cover all their emissions in the following year. The gap can be offset by purchasing CER generated by CDM. Failure to submit a sufficient amount of allowances results in sanction payments whose standard has improved from €30 to €100 in order for trading scheme working order.

The EUA and sCER are typical instruments in carbon market. These instruments have spot, future, option and swap derivatives. As other financial market, carbon future is prevailing instruments in terms of price discovery and hedging. Thus EUA and sCER futures are dominating financial instruments in carbon market.

2.2Price driver and price relationship

As dominating financial instruments in carbon market, EUA and sCER are driven by common factors. Due to their different producing mechanism, and use scope, size and limits, each is also driven by individual factors respectively. Note that whichever was driven, the impact will transfer each other because of inherent interrelations between them.

Literatures categorize the principle driving factors of carbon prices into (i) policy and regulatory issues and (ii) macroeconomic activities and market fundamentals. Since carbon market is a negative utility market and is based fully and strictly on legislation and institutional compulsion, these institutional alteration and corresponding information disclosure will significantly alter carbon price dynamics, especially in earlier EU ETS phrase. The carbon dioxide is mainly emitted by industrial energy consumption, thus carbon price is driven by energy prices in general. Alberola et al.(2008) and Chevallier(2009) verified that carbon price was driven by energy prices, macro economy, institutional and market events.

The EUA are the default carbon asset in the EU ETS. They are distributed by European Member States throughout National Allocation Plans (NAPs), The supply of EUA is fixed in NAPs, which is public information for market participants (2.08 billion per year during 2008–2012). At each phrases, the allocation cap, allocation method (free or auction), allowances duration and banking-and-borrowing between phrases will affect firm's abatement decisions. News related to Phase II NAPs is also main driver (Chevallier, 2009).

As for sCER, the supply of sCER is unknown. The main sources of uncertainty are due to the fact that (i) the supply of primary CER is unknown and difficult to estimate (as it depends on several risks related to the issuance of primary CER); and (ii) the amount of primary CER that will be converted into sCER is also difficult to assess(Trotignon andLeguet,2009). On the demand side, most of the CER demand to date comes from European industrials, which are limited to 13.4% (on average) of surrendered allowances for compliance during Phase II of the EU ETS. Besides, Annex-B countries of the Kyoto Protocol, such as Japan, purchase CER for compliance. Due to import limit and risk premium, the price of EUA is always higher than the price of sCER.

From ETS design, schedule procedure and market share, it seems that EUA is predominant and CER affiliated. The CER are designed to offset the EUA gap, thus the gap of EUA is the derivative demand of CER. The EUA are exchanged broadly as the most liquid asset for carbon trading, which may be explained by the fact that Europe remains to date the major source of demand for that kind of credits. Mansanet-Bataller et al.(2011) confirmed that EUA determine significantly the sCER price path by using variance decomposition analysis. However, the proportions of explanation are sensitive to the order of the variables in VAR when the shocks are contemporaneously correlated. There maybe exists contemporaneously correlated shock, which was neglect by authors.

2.3Carbon price review

Mainstream carbon price literatures focus only on EUA and use uni-variate GARCH model. Paolella & Taschini(2008) used AR-GARCH model with stable and t-distribution empirically to analyze carbon allowance price in EU ETS. Benz and Truck(2009) analyzed the spot price behavior with a Markov–switching model and AR-GARCH model. Daskalakis et al. (2009) examined daily prices from October, 2005–December, 2007 for pricing of EUA future and option. Chevallier(2009) analyzed carbon future on impact of Macroeconomy, energy price and institution by using a threshold GARCH. Alberola et al.(2009) tested the empirical relationship between EUA price changes and the evolution of industrial production at the EU 24 level, and confirmed the impact of the variation of industrial production on EUA price changes in four countries (Germany, Spain Poland and the UK), and underlines the central role played by German power producers on the EU ETS. Mansanet-Bataller et al.(2011) studied the price relationships between EUA and sCER futures by using cointegration analysis, and their driven factors by using two separate TGARCH models respectively. They concluded that EUA are the leading factor in the price formation of sCER and the energy price is common driven factor for EUA and sCER, solely linking of international carbon markets for sCER. They also stated that sCER pricing differs from EUA since it embodies its inherent various uncertainty. Indeed, the future of credit offset mechanisms beyond 2012 looks rather bleak, while the use of CER in Europe is confirmed only until 2020.

3 Data and Methodology

3.1Data

The European Climate Exchange (ECX) is the first largest futures market with market share of approximately 43% for 2007. ECX introduced the EUA future contract in 2005 as first carbon allowance on the globe, however, CER future issued until March 14, 2008. In order to analyze the behavior of futures markets, the most liquid contracts are selected. The carbon futures contracts of maturity December 2008 to December 2012. The data consist of daily closing prices that cover the period from the first CER future available quote up, 14/03/2008 to 31/03/2010, covering approximately three years. The sample size totals 778 observations.

We use the log returns of daily future prices, calculated as $R_{i,t}=100*(logP_{it}-logP_{i,t-1})$. P is future price, R log return. As following, we directly use EUA and CER representing its log return.

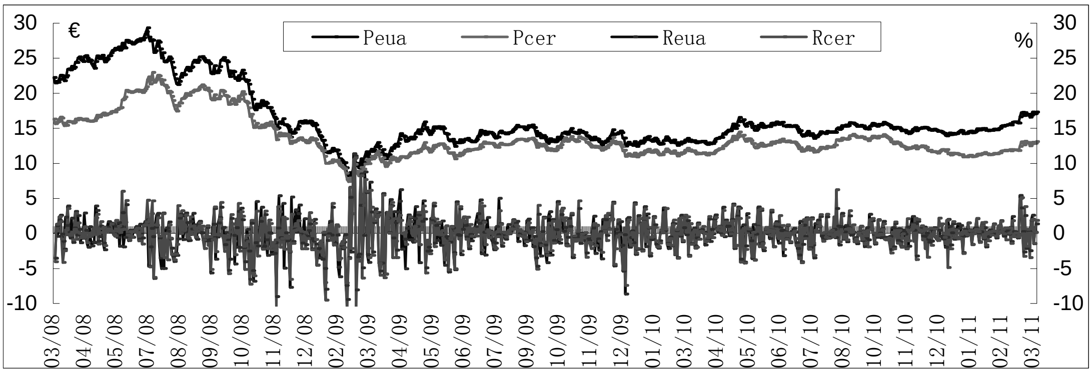

Figure 1　The Time Plots of the EUA and CER Daily Prices

Fig.1 show that the prices of the tow instruments follow a similar movement, and sCER have always remained below EUA. It can be noticed that the two futures start to trend upwards before mid-2008, global finance crisis. After then, two futures are heading towards the trough of spring 2009. The rise in the futures in May -2009 was mainly due to the increased global recovery. Since then to now, two futures fluctuate within limited bonds 10-20€/ton of CO_2. Fig. 1 also displays the returns of the futures with very high volatility during global financial crisis and smaller volatility since May 2009.

Table 1 reports summary statistics for the returns series. The performance of the carbon futures, measured by the average returns, both EUA and CER are negative, has similar volatile. The both have a negative skewness, indicating that large negative returns are more common than large positive returns. In contrast, the CER are strongly negatively skewed. Furthermore CER is leptokurtic, having significantly fatter tails and higher peaks, as the kurtosis statistics are greater than 3. The Jarque-Bera statistics reject the null hypothesis that the returns are normally distributed for all cases. The Ljung–Box Q statistics indicate that there are high order series dependence in both series. Lastly, the augmented Dickey-Fuller (ADF) tests indicate that return series are stationary.

Table 1 Summary Statistics of the Returns of EUA and CER During March 2008 and March 2011

	Mean	S.D	Skewness	Kurtosis	Jarque-Bera	LB-Q(20)	LB-Q^2(20)	ADF
EUA	-0.0323	2.3850	-0.0834	2.3743	183.405***	55.469***	709.178***	-20.132***
CER	-0.0283	2.3500	-0.3034	3.1368	330.481***	51.575***	680.020***	-24.858***

Note: *** represent the levels of significance of 1% LB-Q(k) and LB-Q^2(k) stand for the Ljung–Box Q -statistic for the level and its squared standardized residuals up to 20 lags.

3.2 Methodology

On the basis of the features observed in the previous section, GARCH models will be appropriate. As the aim of the study is to consider the interdependence across the tow carbon instruments, we will use a multivariate GARCH model in the style of the BEKK proposed by Engle and Kroner (1995). Specifically, the following model is used to examine the joint processes relating to the carbon price indices under study.

$$Y_t = \alpha + \Gamma(L)Y_t + \varepsilon_t \qquad \varepsilon_t \mid \Psi_{t-1} \sim N(0, H_t) \tag{1}$$

where $\boldsymbol{Y_t}$ is a 2×1 vector of daily returns at time $\boldsymbol{t}$ and Γ(L), a vector of autoregressive lag polynomials. The diagonal elements in matrix $\boldsymbol{\Gamma}$, γ_{ii}, measure the effect of own past returns while the off-diagonal elements, $\boldsymbol{\gamma_{ij}}$, capture the relation in terms of returns across markets, also known as returns spillover. The 2×1 vector of random errors, $\boldsymbol{\varepsilon_t}$, is the innovation for each market at time t and has a 2×2 conditional variance–covariance matrix, H_t. The market information available at time t−1 is represented by the information set $\boldsymbol{I_{t-1}}$. The 2×1 vector, $\boldsymbol{\alpha}$, represents constants.

Engle and Kroner (1995) proposed the new parameterization for $\boldsymbol{H_t}$, i.e., the BEKK model, to overcome the above two problems. Kroner and Ng (1998) proposed to extend the BEKK model to allow for the asymmetric responses of volatility by using a threshold term in the variance. Defining the threshold $\xi_{i,t}$=max($-\varepsilon_{i,t}$, 0), the asymmetric BEKK model is specified as follows:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B' + D'\xi_{t-1}\xi'_{t-1}D, \qquad \xi_{t-1} = \max(0, -\varepsilon_{t-1}) \tag{2}$$

The last item on the right-hand side captures the asymmetric property of the time-varying variance–covariance. The notation used in Eq (2) is as follows. $\boldsymbol{C}$ is a 2×2 lower triangular matrix of constants while $\boldsymbol{A}$, $\boldsymbol{B}$ and $\boldsymbol{D}$ are 2×2 matrices. The diagonal parameters in matrices $\boldsymbol{A}$ and $\boldsymbol{B}$ measure the effects of own past shocks and past volatility, while the diagonal parameters in matrix $\boldsymbol{D}$ measure the response of its own past negative shocks. The off-diagonal parameters in matrices $\boldsymbol{A}$ and $\boldsymbol{B}$ measure the cross-market effects of shock and volatility, also known as volatility spillover, while the off-diagonal parameters in matrix $\boldsymbol{D}$ measures the response of market i to the negative shocks of other markets, eg., the cross-market asymmetric responses.

All estimations are made using the Winrats 8.01 software package.

4 Empirical Results

The bi-variable asymmetric VAR(2)-GARCH(1,1)- BEKK model is specified. The mean Eq.(1) and time-varying variance–covariance Eq.(2) are estimated simultaneously by the maximum log likelihood method, which converges after 190 iterations and its results are reported in Table 2. The Ljung - Box Q statistics for the 20th orders in the standardized residuals and squared indicates the appropriate specification of the mean and covariance equations.

Table 2 Estimation of Asymmetric BEKK-GARCH Model

mean	C	Γ^1		Γ^2		LB-Q(20)	LB-Q^2(20)
		γ_{i1}	γ_{i2}	γ_{i1}	γ_{i2}		
EUA(i=1)	-0.0668	0.2536***	-0.1948***	-0.2669***	0.2283***	13.4055	21.7942
CER(i=2)	-0.1098	0.0713	-0.0228	-0.1904***	0.1954***	17.6947	13.4815
variance	C	A		B		D	

	C(i,1)	C(i,2)	A(i,1)	A(i,2)	B(i,1)	B(i,2)	D(i,1)	D(i,2)
EUA(i=1)	0.4735***	0.7172***	0.4328***	-0.0696	0.8729***	0.0140	0.3960***	0.6925***
CER(i=2)	--	-0.0480	-0.3011***	0.3327***	0.0837**	0.0642**	-0.0232	-0.2815***
aBEKK	LogL	-2516.00	AIC	6.560	SBC	6.716	HQ	6.620
BEKK	LogL	-2554.37	AIC	6.649	SBC	6.781	HQ	6.700

Note： LogL、AIC、SBC and HQ stand for log likelihood, Akaike information criterion, Bayes schwarz criterion, Hannan-Quinn criterion.

In Γ^1 and Γ^2 in the mean equation, Eq.(1), as the parameters $\gamma^1{}_{11}$, $\gamma^1{}_{12}$, $\gamma^2{}_{11}$and $\gamma^2{}_{12}$, are statistically significant, the returns of EUA depend on EUA and CER first and second lags. In contrast, the insignificant parameters $\gamma^1{}_{21}$ and$\gamma^1{}_{22}$ indicate that the return of CER does not depend on EUA and CER first lags but their second lags.

The matrices A and B reported in Table 2 examine the relationship in terms of volatility as stated in Eq. (2). The diagonal elements in matrix A capture the own ARCH effect, while the diagonal elements in matrix B measure the own GARCH effect. As shown in Table 2, the estimated diagonal parameters, a_{11}, a_{22} and b_{11}, b_{22}, are all statistically significant, indicating a strong GARCH(1,1) process driving the conditional variances of the two instruments. Own past shocks and volatility affect the conditional variance of two instruments.

The off-diagonal elements of matrices A and B capture the cross-market effects such as shock and volatility spillovers among the two instruments. Firstly, we find evidence of uni-directional transmissions from CER to EUA as the pair of off-diagonal parameters, a_{12} and b_{12}, are both statistically insignificant but a_{21} and b_{21} are both statistically significant. News about shocks in the sCER affects volatility of EUA, eg, past shocks of the supply market affects volatility of demand market.

As far as matrix D is concerned, we find evidence of asymmetric response to negative shocks (bad news) of own market for the two instruments, as the diagonal parameters, d_{11} and d_{22} are statistically significant. The sign of the own past shocks affects the conditional variance of these two instruments. We also find evidence of cross-market asymmetric responses. Firstly we find that uni-directional transmissions from EUA to CER. Secondly, we compare the information Criterion of asymmetric and symmetric BEKK model in bottom line of table 2, which imply the asymmetric BEKK is superior to symmetric one. So we conclude that our estimated model is the most fitted and appropriate.

From asymmetric BEKK model estimation, we get a conditional covariance and a dynamic correlation s between the two instruments. The matrix of dynamic correlation depited the change of dynamic correlation, it calculated as: $\rho(r_{1,t}, r_{2,t}) = h_{12,t} / \sqrt{h_{11,t} h_{22,t}}$. The dynamic conditions of Figure 2 clearly show that the entire sample, the correlation coefficient between EUA with sCER is very strong reaching almost 0.9, however it is unstable, there are several weak point below 0.7, even 0.5.

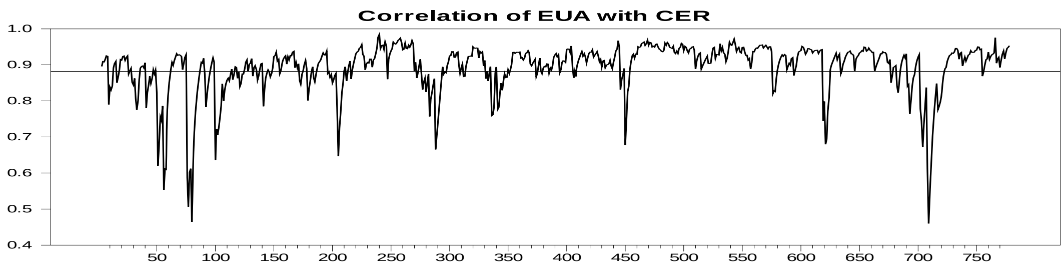

Figure 2 Dynamic Conditional Correlation Between Returns of EUA with Scer

5 Conclusion

In this paper, we have examined carbon market linkages between EUA and sCER in terms of the price and volatility spillover effects during the period March 14, 2008 – March 31, 2011. To our best knowledge, no previous empirical study has focused on price relationship between EUA and sCER. We may decompose our findings in two main contributions.

The sCER as substitute to EUA, two assets are higher interrelation with 0.89, thus two assets are closely integrated. The two prices depict similar movement path due to the strong drive by common factor. Indeed, price fundamentals on the carbon market are essentially a function of allowance supply fixed by the European Commission, and power demand. From this perspective, the transmission of macroeconomic shocks to the carbon market through energy markets volatility spillovers.

The estimated coefficients from the conditional mean price equations indicate that the sCER is bi-direction mean spillover to EUA. In fact, EUA exhibit a significant mean spillover from EUA and sCER both in first and second lags, however, sCER only second lag. The results also indicate that sCER is uni-direction volatility spillover to EUA despite mainstream literature consider the EUA would volatility spillover sCER.

The existence of the uni-direction spillover EUA from sCER to EUA may thus be centrally explained by the conjunction of two factors. Apart from common driven factors, individual factor of sCER is stronger than that of EUA due to heterogeneity and inconstancy of primary CER market. Though institutional change will affect on EUA market, these change are significant but less frequent. In primary CER, there exist a lot of various uncertainties leading to price volatility. Though sCER are largely guaranteed its risk of delivery, others risk of primary market will transmit to overall carbon market through sCER. Secondly there maybe exist Catfish Effect in carbon market, which sCER is stronger and cheaper competitor for EUA. Without import quotas of sCER, it would dump to allowance market, EUA can not sustain its high price under free allocation Phrase Ⅱ in EU ETS. With import limit, low price of sCER would affect EUA in some extent.

The use of market pricing mechanisms can contribute to lower the cost of achieving sustainable goals, result in additional resources, and send a price signal to encourage low-carbon lifestyles to public and investment decisions to firms. The reasonable price of carbon will enhance the cost effectiveness of, and to promote, mitigation actions to support sustainable development.

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