2013

Investability of the European union emissions trading scheme: an empirical investigation under economic uncertainty

Scott J. Niblock
Southern Cross University

Jennifer L. Harrison
Southern Cross University

Publication details

Postprint of: Niblock, SJ & Harrison, JL 2013, 'Investability of the European union emissions trading scheme: an empirical investigation under economic uncertainty', *International Journal of Green Economics*, vol. 7, no.3, pp. 226-240.
Published version available from:
http://dx.doi.org/10.1504/IJGE.2013.058149

Investability of the European Union emissions trading scheme: an empirical investigation under economic uncertainty

Scott J. Niblock* and Jennifer L. Harrison
Southern Cross Business School
Southern Cross University, Gold Coast Campus
Southern Cross Drive, Bilinga, QLD, 4225, Australia
E-mail: scott.niblock@scu.edu.au
E-mail: jennifer.harrison@scu.edu.au
* Corresponding author

Abstract: This paper explores investment characteristics of the European Union Emissions Trading Scheme (EU ETS) during the Global Financial Crisis (GFC). We show that the EU ETS demonstrates significant price volatility, risk-adjusted return under-performance and positive correlations with international equity markets during the GFC, while an OLS regression reveals that carbon market returns are only statistically linked to European equity market returns (both lagged and unlagged). The poor investment performance of carbon assets, interpreted alongside our additional findings and the context of the EU ETS, indicates that during financial crises impacting on developed economies, investors in such economies may need to avoid buy-and-hold strategies and reduce portfolio weightings. Moreover, these investors may need to consider diversifying their portfolio holdings until there is an improvement in economic conditions and/or greater certainty with global climate change policy.

Keywords: carbon; EU ETS; global financial crisis; investment; performance; risk; return.

1 Introduction

The introduction of carbon or "emissions" trading markets has been driven primarily by environmental concerns about climate change. While environmental economics has matured in dealing with climate change issues, its limitations have also been revealed. Carbon trading markets have been severely hampered in recent times by the oversupply of permits due to ineffective environmental policies, a lack of international climate change collaboration, ongoing economic crises, volatile financial and commodity markets and subdued economic activity (World Bank, 2012). As a result, the carbon price has fallen spectacularly in response to the market's belief that trading mechanisms have failed to reduce global greenhouse gases (GHGs), reaching lows of €2 in early 2013.

Despite some of the issues encountered by carbon trading markets, the economic logic behind them is straightforward: emissions are limited by permits, which can be traded, leading to a price for a set amount of emissions being determined by market forces. This price mechanism ultimately produces a shift in production from high to low emissions-producing industries and therefore a cleaner and more sustainable environment.

Carbon pricing currently covers approximately 21% of global GHG emissions. It is estimated that by 2020, carbon pricing will cover 50% of global GHG emissions. This builds on over 6,800 clean development projects in 88 countries, representing $215 billion worth of carbon-related investment (Castellas, 2013). In addition to trading in emissions for scheme compliance purposes (for example, buying/selling permits to cover emissions greater/less than those allocated), risk management, arbitrage and speculation represent other reasons for trading. Hence, carbon markets not only represent an opportunity to reduce pollution globally, but they also increase market liquidity and potentially offer new investment benefits and opportunities for a range of investors with varying purposes. Diversification represents one possible investment opportunity inherent in the new carbon markets. Past research suggests that in periods of high volatility, new and emerging investment markets exhibit diverse performance and so provide diversification benefits to investors (Barry et al., 1998; Harvey, 1993; Roll, 1988). However, there is also evidence to suggest that these benefits are reduced during economic downturns (Conover et al., 2002), precisely when investors are seeking to minimise their exposure to downside risk. During financial crises, contagion and increasing interdependence among markets is evident (Cheung et al., 2010; Patel and Sarkar, 1998), diminishing diversification benefits.

The financial market literature examining the EU ETS has primarily focused on its efficiency and dynamic linkages (see, for example, Boutaba, 2009; Charles et al., 2011; Chevallier, 2010; Daskalakis and Markellos, 2008; Lu and Wang, 2010; Montagnoli and de Vries, 2010; Niblock and Harrison, 2012, 2013; Uhrig-Homburg and Wagner, 2009). However, the evidence is somewhat mixed. Evidence of joint price discovery in spot and forward carbon markets suggests informational efficiency but notably Daskalakis and Markellos (2008) and Niblock and Harrison (2012, 2013) present contrary findings that the EU ETS markets may have been weak-form inefficient in Phase I. On the other hand, Lu and Wang (2010) and Niblock and Harrison (2013) find that, despite the Global Financial Crisis (GFC) and rapid carbon price decline, the EU ETS became more weak-form efficient in Phase II. Niblock and Harrison (2013) also note that the EU ETS may continue to achieve a greater level of efficiency if not hampered by poor policy or further global economic problems.

In this paper, we consider the investability of carbon markets. Specifically, we focus on the European Union Emissions Trading Scheme (EU ETS), the world's first and largest mandatory multi-country, multi-sector cap-and-trade emissions trading scheme. While other carbon markets exist – for example, the Clean Development Mechanism, the Joint Implementation initiative and the NSW Greenhouse Gas Abatement Scheme – the size, scope, organisation and history of the EU ETS enhance its significance in examining carbon market investment characteristics. Furthermore, the EU ETS operating period includes a crisis episode, the GFC, which was the largest such episode since the Great Depression. The GFC began with the U.S. subprime mortgage crisis in 2008, sparking a credit crunch that spilled over into many other economies and markets, especially those more financially integrated and liberalised (Cheung et al., 2010; Claessens et al., 2010). Asset prices fell, liquidity dried up, risk premiums soared and consumer spending sharply declined. Economies then began to contract, leading to a new round of dramatic selling and price falls across global financial markets, particularly in countries with significant international trade and debt exposures. We examine investment characteristics of the EU ETS during this period of crisis and into the beginning of recovery.

This paper is structured as follows. First we describe the EU ETS and briefly review studies examining this market. This is followed by a description of the data used in our study. The paper then outlines the performance of the EU ETS and key international equity markets during a period covering the peak of the GFC and beginning of recovery. Following a consideration of price activity, we examine and discuss correlations and statistical linkages between the EU ETS and key equity markets. The final section provides conclusions.

2 A brief review of the European Union emissions trading scheme

The EU ETS is a mandatory "cap-and-trade" carbon trading scheme. Under such schemes, the regulator sets a maximum quantity of emissions that may be discharged over some fixed time period, divides that quantity into allowances (called European Union Allowances or "EUAs" in the case of the EU ETS), and auctions or otherwise freely allocates them to emitters ("the cap"). Over the commitment period, participants who cannot keep their emissions under the cap can fulfil their scheme obligations by purchasing allowances from those that have invested in efficient technologies or used less carbon-intensive energy sources to reduce their emissions or both ("the trade") (Pearce, 2005; World Bank, 2010). The net effect of these transactions is that scheme participants are able to reduce their emissions at the lowest possible cost. Moreover, carbon trading allows emitters who can cut their emissions cheaply to sell reductions to those who find it more expensive to take action (Tyrell, 2006; World Bank, 2010).

The EU ETS commenced operation on 1 January 2005 and represents a relatively small primary market. EUAs are allocated freely by EU member States under their National Allocation Plans (NAPs), rather than being auctioned; hence, the small primary market. The division of trading in the secondary market between spot and derivatives transactions reveals that over 80% of trading in the EU ETS occurs in forwards and futures markets (Lockie, 2011). Transactions in these markets represent a significant component of the global carbon market, and secondary markets have become increasingly functional, liquid and transparent (World Bank, 2012).

The scheme was designed to operate in three successive Phases to facilitate any necessary modifications. During Phase I (2005-07) the EU ETS covered over 12,000 emitters covering energy activities, mineral oil refineries, coke ovens and companies carrying out activities in ferrous metals, cement, glass, brick making, and pulp and paper industries. Around 40% of EU carbon dioxide emissions were covered by these emitters (Milunovich et al., 2007). Phase I, however, was fraught with controversies. The release of the first verified emissions data indicated that permits had been over-allocated relative to actual emission levels (Burke, 2006), particularly for power producers (Alberola, 2006). This over-allocation led to a price collapse from a high of almost €30/tonne in April 2006 to under €1/tonne in December 2007 (Barclays Capital, 2008). Notably, it took over a year for the surplus EUAs in the market to push the EUA price towards the theoretical zero value. Inexperienced carbon market participants and utility companies holding onto their permits (anticipating higher emissions at the end of the year) contributed to this phenomenon (Barclays Capital, 2008).

In Phase II (2008-2012), regulators refined the scheme based on lessons learnt from Phase I in an effort to provide a more robust and efficient market operation. Some of the changes made in implementing Phase II included:

- improved handling of price sensitive information;
- allowances reissued at the beginning of Phase II at approximately €20;
- lower allocations under National Allocation Plans to increase liquidity;
- broader coverage of industries (for example, chemical, aluminium and aviation/transport) and gases (Milunovich et al., 2007);
- governments can auction EUAs to a maximum of 10% of the allocation; and
- EUAs in Phase II will be bankable into Phase III (2013-20), providing price support and preventing a Phase I style price collapse caused by an inability to carry over unused Phase I EUAs into subsequent periods (World Bank, 2010).

Phase II of the EU ETS also coincided with the GFC. Like most commodities, carbon markets were subjected to significant price volatility during the crisis. During the GFC prices fell from approximately €25 to €7 on large volume. Equally relevant was the crisis of confidence that ensued as the European sovereign debt crisis began to escalate, inciting fears that systemic economic contagion would spread from Greece to other EU economies (particularly to Spain and Italy). Fears about weak demand in the EU ETS further intensified with the: (1) large reduction in EU emissions during the 2008-09 economic downturn; (2) weak industrial recovery in the aftermath of the crises; (3) sizeable investment into domestic renewable energy capacity prior to the GFC and European sovereign debt crisis; (4) long-term oversupply of EUAs and international offsets; (5) overlapping energy and climate policies; and (6) carousel fraud and theft of EUAs, causing some registries to cease trading for up to four months in early 2011 (Castellas, 2013; Lockie, 2011; World Bank, 2012). With compliance demand and prices continually deteriorating over this period, the issue was whether the scheme could encourage long-term low-carbon investments under ongoing economic uncertainty and continue as an efficient mechanism for mitigating GHG emissions.

Since the GFC, and in order to protect GHG emitting installations, Government revenue and consumers, the European Commission (EC) has commenced the process of improving the EU ETS policy design. The carbon market legislative response in the EU included the amendments to Commission Directive 2003/87/EC by Commission Directive 2009/29/EC that required the European Commission (EC) to examine the both integrity and viability of the EU ETS (Castellas, 2013; Lockie, 2011). To address the issues associated with the EU ETS and GFC, the EC carried out reviews which highlight the structure of the carbon market and market oversights. Some of the structural reforms and recommendations reported include (Lockie, 2011, pp. 235 - 237):

- insider trading, market manipulation and supervisory aspects;
- overall integrity of auctions and trading, market transparency and investor protection;
- delaying or “backloading” auctions to address the oversupply of EUAs;
- revision of financial legislation and consistency with energy markets legislation;
- a review of policies concerning the opening and security of registry accounts, and a risk-based review of existing registry account holders;
- facilitation of information exchange between Member States regarding suspicious requests to open an account and tighter controls;
- modification of the EU Registry Regulation to provide a stronger legal basis for measures to protect the integrity of the carbon market and uphold the reputation of the EU ETS;

- comprehensive and cross-border supervision of the carbon market with robust rules for detecting and sanctioning cases of market misconduct;
- a level playing field for intermediaries and trading venues active in the various parts of the carbon market (i.e., primary and secondary, spot and derivatives, etc); and
- a regime where the costs to market participants are proportionate to the benefits of enhanced market integrity.

In the environmental economics literature, the impact of the GFC on the EU ETS has been examined mostly from the perspective of the scheme's ability to fulfil its environmental aims. It is clear that low carbon prices and high volatility limit the effectiveness of long-term planning for sustainable innovations (Knoll and Engels, 2010). Furthermore, the GFC caused a reduction in emissions as production output decreased and the case for emissions trading schemes has been undermined as a result (Butcher and Stilwell, 2009). Emissions from reporting EU ETS installations fell 11% in 2009 mainly as a result of the GFC and total emissions were lower than the total allocation of allowances (World Bank, 2010). This reduced demand for EUAs (Skjærseth, 2010) and resulted in surplus allowances that are now bankable. Hence, these surplus allowances can be used to fulfil emitter obligations during economic recovery, reducing the costs of increasing production and emissions, and slowing the price mechanism's ability to achieve scheme aims. Although the World Bank (2010) argues that many of the surplus allowances were sold during the peak of the GFC in order to raise cash, it could be also be argued that this is just a timing issue in profit taking and that the scheme's ability to deal with economic cycles needs to be carefully considered.

While the success of the EU ETS must be measured against the scheme's ability to reduce carbon emissions and promote sound regulation in the face of economic adversity, a well-functioning emissions market in a financial sense is a necessary condition. Despite the negative attention carbon markets have received in recent times, there is a need for investors to be aware and understand the investability of such markets (Ernst and Young, 2012). Therefore, in the remainder of this paper we focus on exploring the EU ETS from an investor perspective during a period of financial crisis.

3 Data and methodology

The time period of interest in this paper is that of the GFC, which began with increased uncertainty surrounding credit markets in May/June 2008, followed by a long period of tumbling prices in stock markets around the world, and slow recovery from early 2009. The crisis period also coincides with the early stages of Phase II of the EU ETS. Therefore, we begin our analysis at the start of Phase II on 25 February 2008 and use daily closing EU ETS Allowance price observations through until 5 March 2010. Observations are categorised as either spot (*EUAS*) or forward (*EUAF-2010*, *EUAF-2011*, and *EUAF-2012*) price series. We compare carbon market performance to the Dow Jones EURO STOXX total market index (*DJES*), Standard and Poors (S&P) 500 index (*SP500*), S&P All Ordinaries index (*SPAO*), and Shanghai Stock Exchange Composite index (*SSECI*). All of these international equity indices are ranked by weighted market capitalisation. In the absence of a comprehensive benchmark that incorporates carbon and all other risky assets, *DJES* is selected as a relevant market proxy for carbon assets and the European economy combined. The EU 10-year government bond yield is employed to provide a risk-free rate (*RFR*) against which asset performance can be benchmarked.

Data were collected from various exchanges and historical price databases. *EUAS* data are obtained from BlueNext and *EUAF* data from the European Climate Exchange. *DJES* index data are compiled from the Dow Jones EURO STOXX, and the *SP500*, *SPAO*, and *SSECI* index data are sourced from the SIRCA database. *RFR* data are collected from the European Central Bank. The daily log returns of the price series are calculated using the continuously compounded formula:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right), \tag{1}$$

where *Pt* is the price series at time *t*, *ln* is the natural logarithm, and *Rt* represents the log return series.

Statistical relationships or "linkages" between the carbon and international market price series are further examined via ordinary least squares (OLS) regressions. OLS regressions indicate whether a dependent (endogenous) variable is statistically influenced by an independent (exogenous) variable/s. If statistically significant coefficients are discovered then linkages are apparent, suggesting that one series may have predictive ability over the other. In the context of this study, the European spot carbon market log price series ($EUAS_t$) is the dependent variable and a combination of lagged and unlagged European spot carbon and international market log price series ($EUAS_{t-1}$, $DJES_t$, $DJES_{t-1}$, $SP500_{t-1}$, $SPAO_{t-1}$, and $SSECI_{t-1}$) are independent variables. To avoid the "overlap" problem, whereby international financial market operating times can influence the choice of independent market variables (which can lead to further statistical complications with non-contemporaneous variables) (Durand et al., 2001), lagged independent variables are utilised. The use of lagged "log closing price" variables in financial regression analyses ensures that independent market variables are truly independent of each other. However, given that European equity markets operate at the same time as European carbon markets, $DJES_t$ can be considered contemporaneous, and will therefore be investigated with and without lag. OLS regressions are estimated using the following equation:

$$EUAS_t = \alpha + \beta_1 EUAS_{t-1} + \beta_2 DJES_t + \beta_3 DJES_{t-1} + \beta_4 SPAO_{t-1} + \beta_5 SSECI_{t-1} + \beta_6 SP500_{t-1}, \tag{2}$$

4 Empirical results

4.1 EU ETS market performance

Summary statistics are presented in Table 1. At first view, these statistics indicate that the nominal return performance of the EU ETS compared to international equity markets is poor. Underperformance is highlighted by the annualised log returns of both spot and forward price series. *EUAS* and *EUAF-10-11-12* delivered annualised returns of -19.85%, -25.03%, -24.73%, and -24.40%, respectively, in Phase II. Returns were below the European equity market benchmark return (-10.22%). Negative returns across all price series reflect the dampening effect of the GFC and ensuing global recession on carbon and international equity market investment.

Price volatility is clearly reflected in carbon markets across the period by the large spreads between minimum and maximum returns, high standard deviations and betas. Beta is calculated using *DJES* as the reference market. *EUAS* and *EUAF-10-11-12* had standard deviations/betas of 2.66%/1.25, 2.64%/1.25, 2.63%/1.22, and 2.54%/1.17, respectively. Standard deviations were higher than the European equity market benchmark standard deviation (1.85%), indicating that carbon was riskier than the broader market during the GFC. Also, spot and forward carbon betas are positive and greater than one suggesting that carbon markets, on average, exhibit more systematic risk than the broader European equity market. The volatility in carbon markets displayed during the period is in line with expectations, given that emerging markets tend to display such price characteristics during the early stages of market growth.

[Insert Table 1 here]

Table 1 also shows the Sharpe (1966) ratio for each price series, which is the ratio of the average annualised return less the risk free rate to the standard deviation. The ratio therefore indicates the excess return earned per unit of total risk and so higher ratios denote better risk-adjusted performance. Comparison of the Sharpe ratios shows that *EUAS* (-8.93) and *EUAF-10-11-12* (-10.95, -10.89, and -11.13, respectively) underperformed *DJES* (-7.63) and the other international equity price series (except *EUAS* versus *SSECI*) on a risk-adjusted basis. The last column of Table 1 shows statistics relating to the shape of the return distributions. The Jarque-Bera (1980) test statistics indicate that the log return series of all carbon and international equity markets do not follow a normal distribution. However, non-normality of returns is not an unusual phenomenon in financial time-series (Conover et al., 2002; Ma 2004).

4.2 Price activity

In this section, we examine price activity in the carbon markets during our study period. In an efficient market, futures prices should move conjointly with spot prices (Daskalakis and Markellos, 2008; Fama, 1991). This is portrayed in Figure 1. During the period, spot and futures prices moved closely in line with each other, suggesting an efficient flow of information between these markets and conditions conducive to effective risk management.

[Insert Figure 1 here]

Figure 1 also shows the commencement of a downward trend in carbon prices in late May 2008. This coincides with increased uncertainty about the future of large U.S. financial institutions, such as America International Group (AIG), Bear Stearns, Freddie Mac, Fannie Mae and Lehman Brothers, at that time. Around the world, asset prices were tumbling and carbon permits were no exception.

Carbon price activity is compared to international equity markets in Figure 2. Equity markets were already falling at the beginning of Phase II of the EU ETS. *SSECI* fell more sharply than other equity markets and bottomed out earlier. The developed markets in the figure (*DJES, SP500* and *SPAO*) moved closely throughout the entire period under consideration, as might be expected from these highly integrated markets. By January 2009 these markets and the EU ETS had bottomed and began to rally. However, the recovery was short-lived for carbon markets, reaching a post-crisis peak in April 2009. The rally in equity markets lasted a little longer than carbon markets and, despite a flattening out in all markets by the middle of 2009, equity markets had clearly regained more ground. Carbon markets maintained prices around their April 2009 peak until the end of the period covered by our data set.

[Insert Figure 2 here]

There are two likely reasons for the lacklustre recovery of carbon prices. Firstly, it became clear that global economic recovery was going to be slow. As a result, demand for carbon abatement remained soft and carbon markets traded without direction. Secondly, uncertainty surrounding international agreements on responses to climate change was increasing. This uncertainty peaked when negotiations broke down at the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in December 2009.

4.3 Co-movements among carbon markets and with equity markets

Having considered key performance statistics and price activity during the study period, we now examine correlations between spot and forward carbon prices, and correlations between the carbon markets and equity markets. Low correlations between asset prices are a favourable occurrence for portfolio investors, as non-systematic risk can be lowered and returns enhanced by combining such assets. Correlations between financial assets can also have implications for market efficiency theory (for instance, two asset prices that share a robust positive correlation or "co-movement" may infer return predictability in one or the other, or both) (Barry et al., 1998; Harvey, 1993).

Correlations between carbon markets and equity markets are shown in Table 2. The carbon markets exhibit perfect or almost perfect positive correlations, reflecting our earlier observation about efficient price formation between spot and forward carbon prices during the study period. Relationships between carbon markets and equity markets are not as high but also demonstrate positive correlations. Carbon markets are most correlated with *DJES*, *SP500* and *SPAO*, with positive correlations ranging between 0.66 and 0.77. Correlations with the Chinese stock market (*SSECI*) were also positive but much lower than other equity markets, ranging from 0.13 with the 2012 forward market and 0.19 with the spot market. It is also worth noting that, as depicted in Figure 2, the correlations between the *DJES*, *SP500* and *SPAO* developed equity markets are close to 1.

[Insert Table 2 here]

These correlations may reflect the general tendency for diversification benefits to fall during crisis events. Certainly, carbon markets and international equity markets are not perfectly positively correlated, which indicates some diversification opportunities are available. However, the greatest diversification benefits would appear to be gained by combining investments in the emerging carbon market with those in the segmented and geo-politically insulated Chinese stock market. A combination of carbon and more established markets would seem to provide less benefit. The correlations, however, are for the entire period under study.

Consideration of these correlations in combination with Figure 2 makes it reasonable to suggest that the low positive correlations between carbon markets and the Chinese stock market may simply be a reflection of the divergence of these two series at several points during the first half of the period. For example, while the carbon market was still rising in the early part of the period, which was before ongoing impacts on the real economy and emissions may have been fully understood, the Chinese stock market was falling on the back of overstated values and speculation about its ability to maintain growth as developed market contagion spread. By the time of recovery, however, it is clear that all markets considered here appear to move more closely.

4.4 Regression analysis

An OLS regression analysis is carried out to further explore possible statistical linkages running from international markets to the European spot carbon market during the GFC period. The findings are provided in Table 3.

[Insert Table 3 here]

The overall regression is significant (F = 12324, p<.01). Table 3 indicates that the coefficients for the lagged carbon spot price (*EUAS (-1)*) and the contemporaneous European stock market (DJES) are positive and significant, while the coefficient for the lagged European stock market (*DJES (-1))* is negative and significant. These coefficients suggest that a 1% change in the spot carbon price and European stock market in the previous trading day, and a 1% change in the European stock market today, results in a 0.99%, -0.46% and 0.51% change, respectively, in the spot carbon market today. Failure to discover statistical significance for the remaining independent variables implies that there are no apparent statistical linkages between European carbon markets and Australian, Chinese and U.S. stock markets during the period under investigation. However, the close movements between developed stock markets and closer commonalities in the political and economic contexts of the European stock market and EU ETS may be reflected in the dominance of the European stock market in predicting carbon prices.

5 Conclusions and discussion

In this paper we have examined the investment characteristics of the EU ETS from the beginning of Phase II through the period of falling prices in financial markets due to the onset of the GFC and into the beginning of price recovery. While previous studies of the EU ETS have considered its efficiency and dynamic linkages, or its ability to realise its environmental aims, return and risk characteristics from an investment perspective have been overlooked. Our study fills this gap by providing a presentation of a range of carbon market investment characteristics and by considering these characteristics within the wider context of the GFC.

The results show that European carbon markets demonstrate investment characteristics such as high volatility, risk-adjusted return under-performance and positive correlations with four key international equity markets. Also, an OLS regression reveals that carbon market returns are statistically linked to European equity market returns (both unlagged and lagged). Interpreted within the broader context surrounding carbon markets and the time period considered, these findings suggest that global climate change policy uncertainty and the GFC have promoted a highly speculative and risky trading environment for carbon assets and reduced their desirability as a viable investment vehicle. Further, the allocation of private capital toward the rollout of low-carbon technologies has been inhibited by the absence of reliable long-term price signals, which have ultimately been compounded by skittish financial markets that prefer exposure to less risky asset classes during periods of economic crisis. If these trends continue, the investment potential of carbon markets is doubtful.

Our study has some interesting conclusions and implications when compared with the broader literature on investments in new and emerging markets. First, our carbon market findings are consistent with Errunza (1997) and Blavy (2002) who, in other contexts, found that large price swings are not unique to emerging markets but that these new markets exhibit a higher degree of volatility than developed markets. Second, our findings are inconsistent with Barry et al., (1998), Harvey (1993) and Roll (1988) who argue that during periods of general high volatility (as in the case of the GFC) emerging markets should exhibit diverse performance and provide much needed diversification benefits. In contrast, we found that during the GFC correlations between carbon markets and developed equity markets were strongly positively correlated. Instead, it would seem that emerging market participants like those in China may receive the greatest diversification benefits from investing in the EU ETS. In combination with our regression findings, this suggests that the world's largest carbon market may be linked most closely with the fate of the European Union and may not present a useful addition to the portfolio of a European investor.

Overall, the poor investment characteristics associated with carbon assets during the GFC suggests that investors may need to avoid buy-and-hold strategies, reduce their portfolio weightings and consider diversifying their portfolio holdings until there is an improvement in economic conditions that will promote increased demand for carbon allowances. These actions may also best be followed until there is greater certainty in global climate change policy. The conundrum for carbon markets is that if non-compliance investment trading is avoided, liquidity in these markets will be reduced and the ultimate aim of these markets may be compromised.

For carbon trading schemes to make an impact on emissions, the carbon price needs to increase dramatically to create an incentive for industry to move to competitive and cleaner energy and/or technologies. Carbon trading should be seen as a commercial opportunity to reduce carbon emissions and for global investors seeking to diversify risk across alternative asset classes. The EU ETS may prove to be an effective global climate change policy mechanism but has been unable to make an impact so far due to the constraints mentioned throughout this paper. Market-based mechanisms could achieve their aim of changing consumer and industry behaviour; however, carbon trading is not a “silver bullet” solution to reducing emissions. Carbon trading schemes need to be flanked with flexible economic policy incentives (i.e., climate funds and direct action, financial instruments and technology innovation) which deliver clearer price signals, encourage private sector participation, deliver low cost solutions for climate change mitigation and adaptation, and promote clean energy awareness/education in order to assist industries/businesses and individuals in their transition to a more sustainable economy.

It is imperative that international carbon trading schemes have linkages to the EU ETS, both developed and emerging economies and other environmental markets. While the 2011 Durban Platform (whereby all countries, reached an international climate agreement) is a good start, the scope and targets of the Platform are not yet established (Ernst and Young, 2012). Arguably, the international negotiations at COP 21 in Paris in 2015 for a unified global carbon market and emissions reductions target by 2020 will be a significant platform from which to launch the next campaign against climate change (Castellas, 2013). Carbon trading schemes are unlikely to be successful if they remain fragmented in their pursuit to curb global GHGs and mitigate environmental risks associated with climate change. To be successful, carbon markets require policy and regulatory certainty, competition, ambitious emission reduction targets, inter-operability and transparency. A better understanding of the green economy will promote better climate change policies, economic growth, and a cleaner, safer and prosperous environment for future generations. Perhaps crisis events like the ones recently encountered provide a limited window of opportunity to acknowledge that there is a problem with the current way of economic thinking: there are likely to be far more risky economic, environmental and societal crises in the future, and a shift to a more sustainable approach is not only desirable, but necessary!

References

Alberola, E., (2006). The informational efficiency of the EU ETS: An empirical evaluation on the spot and futures prices. Working Paper, University of Paris, France.

Barclays Capital, (2008). *Introduction to the Emissions Market*. Barclays, London, U.K.

Barry, C.B., Peavy, J.W., III and Rodriguez. M., (1998). Performance characteristics of emerging capital markets. *Financial Analysts Journal*, Vol. 54, No. 1, pp. 72-80.

Blavy, R., (2002). Changing volatility in emerging markets: A case study of two Middle Eastern stock exchanges. *Revue Entente Cordiale*, Autumn-Winter, 1-35.

Boutaba, M.A., (2009). Dynamic linkages among European carbon markets. *Economics Bulletin*, Vol. 29, No. 2, pp. 499-511.

Burke, M., (2006). Drop in EU carbon prices baffles analysts. *Environmental Science and Technology*, Vol. 40, No. 15, pp. 4534-4535.

Butcher, B.S., and Stilwell, F., (2009). Climate change policy and economic recession. *Journal of Australian Political Economy*, Vol. 63, pp. 108-125.

Castellas, P., (2013). Where's the world going on carbon trading? Accessed: 29 September 2013, http://www.businessspectator.com.au/article/2013/6/7/carbon-markets/wheres-world-going-carbon-trading.

Charles, A., Darné, O., and Fouilloux, J., (2011). Testing the martingale difference hypothesis in CO_2 emission allowances. *Economic Modelling*, Vol. 28, No. 1-2, pp. 27-35.

Cheung, W., Fung, S., and Tsai, S-C., (2010). Global capital market interdependence and spillover effect of credit risk: evidence from the 2007-2009 global financial crisis. *Applied Financial Economics*, Vol. 20, No. 1-2, pp. 85-103.

Chevallier, J., (2010). A note on cointegrating and vector autoregressive relationships between CO_2 allowances spot and futures prices. *Economics Bulletin*, Vol. 30, No. 2, pp. 1564-1584.

Claessens, S., Dell'Ariccia, G., Igan, D., and Laeven, L., (2010). Cross-country experiences and policy implications from the global financial crisis. *Economic Policy*, Vol. 25, No. 62, pp. 267-293.

Conover, C.M., Jensen, G.R., and Johnson, R.R., (2002). Emerging Markets: When are they worth it? *Financial Analysts Journal*, Vol. 58, No. 2, pp. 86-95.

Daskalakis, G., and Markellos, R., (2008). Are the European carbon markets efficient? *Review of Futures Market*, Vol. 17, No. 2, pp. 103-128.

Durand, R.B., Koh, S.K., and Watson, I., (2001). Who moved Asian-Pacific stock markets? A further consideration of the impact of the U.S. and Japan. *Australian Journal of Management*, Vol. 26, pp. 125-145.

Ernst and Young, (2012). The future of global carbon markets: The prospect of an international agreement and its impact on business. Accessed 29 September 2013, http://www.ey.com/Publication/vwLUAssets/The_future_of_global_carbon_markets/$FILE/The_future_of_global_carbon_markets.pdf.

Errunza, V.R., (1997). Research on emerging markets: past, present, and future. *Emerging Markets Quarterly*, Vol. 1, No. 3, pp. 5-18.

Fama, E.F., (1991). Efficient capital markets: II. *Journal of Finance*, Vol. 46, No. 5, pp. 1575-1617.

Harvey, C., (1993). Portfolio investment using emerging markets and conditioning information. Working Paper, World Bank, Washington DC.

Jarque, C.M., and Bera, A.K., (1980). Efficient tests for normality, homoskedasticity and serial independence of regression residuals. *Economics Letters*, Vol. 6, No. 3, pp. 255-259.

Knoll, L., and Engles, A., (2010). Exploring the linkages between carbon markets and sustainable innovations in the energy sector: lessons from the EU Emissions Trading Scheme, in Engles, A. (ed.) *Global Transformations towards a Low Carbon Society Working Paper Series*, 2, University of Hamburg, Klima Campus, Hamburg.

Lockie, D.L., (2011). Closing Pandora's Box: A case for carbon market integrity after the Global Financial Crisis: Conditioning ownership of the right to emit greenhouse gases in an Australian emissions trading scheme, PhD Dissertation, ePublications@bond, Faculty of Law.

Lu, W., and Wang, W., (2010). Weak-form efficiency of European Union emission trading scheme: evidence from variance ratio tests. *International Journal of Green Economics*, Vol. 4, No. 2, pp. 183-196.

Ma, S., (2004). The Efficiency of China's Stock Market. Ashgate Publishing, Aldershot, U.K.

Milunovich, G., Stegman, A., and Cotton, D., (2007). Carbon trading: theory and practice. *JASSA*: *The FINSIA Journal of Applied Finance*, Vol. 3, pp. 3-9.

Montagnoli, A., and deVries, F.P., (2010). Carbon trading thickness and market efficiency. *Energy Economics*, Vol. 32, No. 6, pp. 1331-1336.

Niblock, S.J., and Harrison, J.L., (2012). Do dynamic linkages exist among European carbon markets. *International Business & Economics Research Journal*, Vol. 11, No. 1, pp. 33-44.

Niblock, S.J., and Harrison, J.L., (2013). Carbon markets in times of VUCA: A weak-form efficiency investigation of the EU ETS Phase II. *Journal of Sustainable Finance & Investment*, Vol. 3, No. 1, pp. 38-56.

Patel, S.A., and Sarkar, A., (1998). Crises in developed and emerging stock markets. *Financial Analysts Journal*, Vol. 54, No. 6, pp. 50-59.

Pearce, F., (2005). A most precious commodity. New Scientist, Vol. 185, No. 2481, pp. 6-7.

Roll, R., (1988). The international crash of October 1987. Financial Analyst Journal, Vol. 44, No. 5, pp. 19-35.

Sharpe, W.F., (1966). Mutual fund performance. The Journal of Business, Vol. 39, No. 1, pp. 119-138.

Skjærseth, J.B., (2010). EU emissions trading: legitimacy and stringency. *Environmental Policy and Governance*, Vol. 20, pp. 295-308.

Tyrell, K., (2006). Linking the world with emissions trading. ENDS Report, Vol. 380, pp. 34-37.

Uhrig-Homburg, M., and Wagner, M.W., (2009). Futures price dynamics of CO_2 emission certificates - an empirical analysis. *Journal of Derivatives*, Vol. 17, No. 2, pp. 73-88.

World Bank, (2010). *State and Trends of the Carbon Market*, World Bank Institute, Washington DC.

World Bank, (2012). *State and Trends of the Carbon Market*, World Bank Institute, Washington DC.

Table 1 Summary statistics

Series	Min. daily return (%)	Max. daily return (%)	Mean daily return (%)	Return p.a. (%)	Std Dev. (%)	Beta	Sharpe ratio	Jarque-Bera
EUAS	-10.29	10.55	-0.08	-19.85	2.66	1.25	-8.93	61*
EUAF-10	-9.30	11.35	-0.10	-25.03	2.64	1.25	-10.95	80*
EUAF-11	-9.06	11.53	-0.01	-24.73	2.63	1.22	-10.89	84*
EUAF-12	-9.33	11.75	-0.01	-24.40	2.54	1.17	-11.13	103*
DJES	-7.87	9.30	-0.04	-10.22	1.85	1	-7.63	386*
SP500	-9.47	10.96	-0.03	-8.14	2.12	N/A	-5.69	542*
SPAO	-8.55	5.36	-0.03	-7.91	1.60	N/A	-7.38	177*
SSECI	-6.98	9.03	-0.07	-17.26	2.23	N/A	-9.51	52*

Notes: This table reports summary statistics for EU ETS and equity markets 25 February 2008 to 5 March 2010 which represents 530 observations for each price series. *EUAS* is the spot EU ETS market price series. *EUAF-10, EUAF-11* and *EUAF-12* are the forward EU ETS market price series for 2010, 2011 and 2012, respectively. *DJES* is the Dow Jones EURO STOXX total market index. *SP500* is the Standard and Poors (S&P) 500 index. *SPAO* is the S&P All Ordinaries index. *SSECI* is the Shanghai Stock Exchange Composite index. * denotes statistical significance at 5% level and hence rejection of the null hypothesis of a normal distribution in the price series.

Table 2 Correlations of carbon and international equity markets

	EUAS	*EUAF-10*	*EUAF-11*	*EUAF-12*	*DJES*	*SP500*	*SPAO*	*SSECI*
EUAS	1.00							
EUAF-10	1.00	1.00						
EUAF-11	1.00	1.00	1.00					
EUAF-12	0.99	1.00	1.00	1.00				
DJES	0.77	0.74	0.73	0.72	1.00			
SP500	0.76	0.74	0.73	0.73	0.99	1.00		
SPAO	0.72	0.68	0.70	0.66	0.98	0.98	1.00	
SSECI	0.19	0.14	0.14	0.13	0.64	0.63	0.69	1.00

Notes: This table reports correlations among the log prices of EU ETS markets and with log indices for international equity markets during Phase II of EU ETS operation. *EUAS* is the spot EU ETS market price series. *EUAF-10*, *EUAF-11* and *EUAF-12* are the forward EU ETS market price series for 2010, 2011 and 2012, respectively. *DJES* is the Dow Jones EURO STOXX total market index. *SP500* is the Standard and Poors (S&P) 500 index. *SPAO* is the S&P All Ordinaries index. *SSECI* is the Shanghai Stock Exchange Composite index.

Table 3 OLS regression analysis of spot carbon market and international equity markets

Series	**Coefficient**	***t*-stat**
Constant	-0.0904	-0.5296
EUAS (-1)	0.9917	105.9938*
DJES	0.5089	8.0597*
DJES (-1)	-0.4639	-5.5618*
SPAO (-1)	0.0343	0.8961
SSECI (-1)	0.0010	0.1220
SP500 (-1)	-0.0615	-1.0117

Notes: The dependent test variable is $EUAS_t$. The independent test variables are $EUAS_{t-1}$, $DJES_t$, $DJES_{t-1}$, $SPAO_{t-1}$, $SSECI_{t-1}$, and $SP500_{t-1}$. * denotes statistical significance at 5% level.

Figure 1 Price activity in the carbon markets

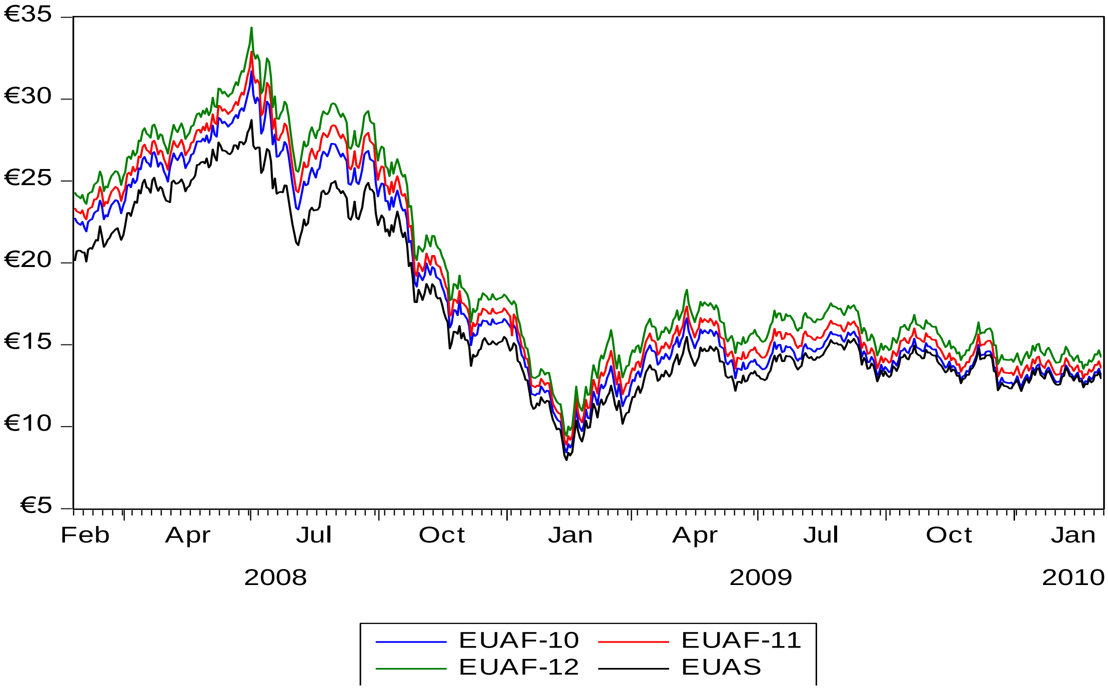

Figure 2 Comparison of EUAS and equity market price series