Climate Economics Chair Publications

Working Paper Series

n° 2011-01

CO_2 Prices and Portfolio Management during Phase II of the EU ETS

Maria Mansanet-Bataller[1]

Since the launch of the European Union Emission Trading Scheme (EU ETS), the interest in the trade of EUAs is constantly increasing among academics and market participants. The objective of this article is twofold: (i) a detailed description of this new market is provided for portfolio managers, and (ii) a comprehensive study of the implications of including Phase II EUAs in diversified portfolios is undertaken using as expected returns both historical and risk-adjusted returns. The results show that the opportunity set do not vary if we consider historical returns and that if we take into account risk-adjusted returns the efficient set only increases if the investor takes a short position in Phase II EUAs.

JEL Classification: G11

Keywords: CO2 Futures, Portfolio Management.

A first version of this paper, entitled "CO2 Prices and Portfolio Management" and jointly written with Angel Pardo, analysed the benefits of including EUAs in diversified portfolios using a different database for the sample period from April 22nd 2005 to January 31st 2008. I would like to thank Philip Dumont (Société Géneral), Paul MacManus (AFI), Emilie Alberola and Nicholas Berghmans (CDC Climat Research) for their help and for providing the necessary data to perform this study and Natalie Frank for her attentive reading. The author is grateful for the financial support of the Ministerio de Educación y Ciencia (reference number CGL2006-06367/CLI and EDU/3432/2010), the FEDER, the Cátedra Finanzas Internacionales-Banco Santander.

1. Department of Financial Economics, Faculty of Economics, University of Valencia, Avda de los Naranjos s/n, 46022 Valencia, Spain, and Invited Researcher at the Climate Economics Chair, Paris, France. maria.mansanet@uv.es

Climate Economics Chair
Paris-Dauphine University
CDC Climat

1. INTRODUCTION

The European Union launched, in 2005, the European Union Emission Trading Scheme (EU ETS), in order to reduce its industrial European CO_2 emissions. The EU ETS is currently organized in three phases: Phase I, a pilot period that ran from January 2005 to December 2007, Phase II, coincides with the Kyoto Protocol commitment period, comprises the years 2008 to 2012. Phase III will start in January 2013 and will last until December 2020. For each phase of the scheme, European Member States cap, via their National Allocation Plans (NAP), CO_2 emissions of the large CO_2 emitting European installations. Through the NAPs, installations receive European Union Allowances (EUA), either free of charge or through auctioning, that allow the emission of one tonne of CO_2 in the atmosphere. In order to be "in compliance", each installation has to annually surrender the same amount of permits as its real emissions, at a pre-defined time. The EU ETS facilitates installations achieving their reduction targets by organizing the trade of the EUAs in several spot, futures and option markets. However these are not the only possible participants in the EU ETS: every natural or legal person with an account on the trading platform is eligible to trade EUAs. Thus, the interest of studying the diversification benefits of including this new asset in diversified portfolios.

Since Markowitz (1952), many authors have studied the benefits of diversification in a broad range of scenarios. Grubel (1968) and Eun and Resnick (1988), among others, try to show if a portfolio is better diversified when including foreign assets or not, also known as international diversification. In other cases, the authors study diversification opportunities when introducing new assets, in other words, asset diversification. For example, Ibbotson and Siegel (1984), Kuhle (1987) and Chandrashekaran (1999), among others, compare the Real Estate Investment Trusts with other investment opportunities in order to study the potential of these assets to improve portfolio diversification. Also, Jensen et al. (2002), Gorton and Rouwenhorst (2006), and Erb and Harvey (2006) analysed the impact of introducing commodities indices such as the Goldman Sachs Commodity Index (GSCI) in management portfolio.

This paper will focus on the diversification effects of introducing Phase II EUAs in various diversified portfolios. The study of the effects of including Phase II EUAs in a diversified portfolio is pertinent and timely because: (i) Phase I of the EU ETS, which was considered an isolated pilot phase, is not of much interest for market participants and (ii) the interest of investors in carbon markets is constantly increasing (Garrouste et al. (2010)). Hence, the aim of this article is twofold. Our first goal is to provide a description of the EU ETS for potential participants other than those already covered under the European directive and more specifically for capital managers that could exploit the opportunities of this new tradable asset in diversification terms. Hereby, we will also analyse under which conditions the existence of this new asset (the EUA) will enlarge the investment opportunities for a European investor in Phase II of the EU ETS. To the best of our knowledge, the literature on portfolio management using carbon markets is still very limited. This paper is the continuity of the analysis performed in Mansanet-Bataller and Pardo (2008a) with a most suitable database and a longer sample period. The results obtained will be of interest for both academic and market participants.

The remainder of the paper is organized as follows. In the next section the EUA's main characteristics as a new tradable asset are presented. In section 3, the data used in the study are described as well as the analytical framework. Section 4 analyses the effects of the inclusion of Phase II EUAs in several diversified portfolios, in terms of return-standard deviation trade-off. Finally, section 5 summarizes the most important results of the paper and adds some concluding remarks.

2. CO_2: A NEW TRADABLE ASSET

By ratifying the Kyoto Protocol, industrialized countries committed to reduce their greenhouse gases emissions (GHG) by at least 5% from 1990 emissions levels for the commitment period from 2008-2012. In order to facilitate the fulfilment of the emission reduction targets, the Kyoto Protocol establishes three flexibility mechanisms one of them being emission trading. This flexibility mechanism offers the possibility to reduce the cost of emission reductions by allowing those countries with lower abatement costs to sell their surplus allowances to the rest of the countries as long as they fulfill their reduction objectives. Thus, the different units that can be used for compliance under the Kyoto Protocol, Certified Emission Reductions (CER), Emission Reduction Units (ERU), and Assigned Amount Units (AAU), can be traded either Over-the-Counter (OTC) or in organized markets around the world.[1] However, the most important organized carbon market either in terms of installations covered (around 11,000) and in

[1] Note that all of those units allow for the emission of one ton of CO_2 in the atmosphere. For a detailed description see Mansanet-Bataller and Pardo (2008b) and Ellerman et al. (2010).

terms of real emissions considered (2082.7 Million tons for the period 2008-2012) is the EU ETS.

Concretely, the European Union launched the EU ETS in January 2005 to reduce its greenhouse gases emissions at the lowest cost. The EU ETS consists of a cap and trade system where the emissions of the installations under the scheme are capped and exchange of allowances is permitted in order to achieve compliance. Even if the installations under the EU ETS have a global cap of CO_2 emissions for each phase and receive EUAs throughout the NAPs, the EUAs are available for the installations at the beginning of each year and compliance is verified the year after by the European Commission.[2] In order to be in conformity, the installations can also use, up to a predefined limit, the “Kyoto credits” (CERs and ERUs) in addition to the EUAs. Note that throughout this scheme, the European Member States delegate to the installations of the most greenhouse gases emissions intensive sectors part of the emissions reductions effort.

The EU ETS is organized in consecutive phases: Phase I started in January 2005 and lasted until December 2007. Phase II of the EU ETS, coincides with the Kyoto Protocol commitment period, beginning in January 2008 and lasting until December 2012. Phase III of the EU ETS will start in January 2013 and will last until December 2020 whether or not an international agreement on global emissions reductions exists.

As banking (the transfer of allowances from one phase to the next one) and borrowing (the transfer of allowances from one phase to the previous one) was not allowed between Phase I and Phase II of the EU ETS, the EUAs of Phase I and the EUAs of Phase II were, in fact, two differentiated assets whose price evolution corresponded to supply and demand factors within each phase. In Figure 1-A (-B) the spot (futures) price evolution of EUA for both Phases is presented.

[Please, insert Figure 1]

One can observe in Figure 1-B, that even if both futures contracts started to trade at similar prices at the beginning of Phase I, they discorrelate around April 2006. At this moment, the market participants realized that for Phase I of the EU ETS the number of

[2] At the end of April of the year after the real emissions have taken place, each installation must surrender the same amount of permits as its real and verified emissions of the year.

allowances distributed among the installations under the scheme was higher than the forecasts of their real emissions. Thus, as banking of allowances was not allowed between phases, the value of Phase I EUAs diminished rapidly. At the end of Phase I the price of a EUA was close to zero. By contrast, prices for Phase II of the EU ETS followed a very different path. From April 2006 to May 2007 they also diminished but found a floor at 12 Euros in February 2007 after which prices started to increase until reaching 25 Euros in May 2007. Since then, Phase II EUA prices stayed between 20 and 25 Euros and in April 2008 they continued to increase up to a range of 25 and 30 Euros until the end of July 2008, reaching a peak of 29.33 Euros July 1st 2008. Then EUA prices started to decrease until they reached near 8 Euros in February 2009. Since then to the end of the sample period (November 3rd 2010) they have been moving in a range of 12 and 17 Euros.

It is important to underline that as banking, but not borrowing, between Phase II and Phase III of the EU ETS is allowed, Phase II EUAs can be used for compliance during Phase III, but not the other way round. Thus, if there is an excess of allowances for Phase II of the EU ETS, it is not expected that Phase II EUA prices will go down to zero as in Phase I because they can be banked and used during Phase III of the EU ETS.

The EU ETS accelerated the trade of EUAs in organized markets, even if since 2004 it was possible to trade EUAs forward contracts over-the-counter (OTC). As mentioned before, it is possible to trade EUAs on exchanges using spot, futures and options contracts which are available on different European trading platforms.

Mansanet-Bataller and Pardo (2008b) analyse the different organized markets where it is possible to trade carbon permits (both EUAs and CERs) and the type of contracts that can be traded in each market (spot, futures and option contracts depending on which market one is considering). Their study presents several important conclusions that are confirmed in the Figures below: (i) the most traded carbon asset among the different assets available for Kyoto compliance in organized markets in terms of volume are EUAs (Figure 2-A), (ii) the volumes in the futures market are much higher than in spot markets (Figure 2-B), (iii) among the different futures contracts allowing EUAs trading, the one that presents the highest volume is the EUA nearest December futures contract, (Figure 2-B), (iv) the most important Futures market in terms of volumes is the European Climate Exchange (ECX) (Figure 2-C), (v) the most important spot market in terms of volumes is BlueNext (Figure 2-C).

[Please, insert Figure 2]

Additionally, the authors point out that (v) several existing European organized carbon markets present highly correlated prices both in spot and futures contracts (Figure 3-A), and (vi) CER prices are very correlated to EUA prices (Figure 3-B). [3]

[Please, insert Figure 3]

The above mentioned characteristics of the European carbon market allow one to justify that the most suitable Phase II carbon asset to be included in an already diversified portfolio is the Phase II EUA December front futures contract traded on ECX. This is not only the most traded EUA contract but also the longest available price series of Phase II EUAs.

It is interesting to note that ECX, which is based in London, trades electronically and continuously, from 7:00 am to 5:00 pm UK Local Time, coinciding with spot trading on Bluenext, several carbon contracts. Trading of Phase II EUA Futures contracts started in April 22nd 2005.[4] Since then, quarterly contracts are listed for this phase with expiration dates in March, June, September and December. The underlying asset of the futures contracts are Phase II EUAs of the EU ETS. The trading unit is one lot of 1,000 Emission Allowances (one lot is also the minimum trading size). The futures contracts traded on ECX quote in Euros and Euro cents per metric ton. The tick size is €0.01 per tonne (which is equivalent to €10.00 per lot). The minimum price fluctuation is €0.01 and there is no maximum fluctuation limit. Additionally, it is also possible to make block trades with a minimum size of 50 lots, but neither the Exchange for Physical (EFPs) nor the Exchange for Swaps (EFSs) are available. Delivery is possible in all the registries belonging to the clearinghouse public list, from which the clearinghouse will accept and will deliver emission allowances. The contracts are physically deliverable during the delivery period by the transfer of emission allowances from the seller's account to the ICE Clear Europe account and from the ICE Clear Europe account to the

---

[3] Please, see Mansanet-Bataller et al. (2011) for a deeper analysis of the EUA-sCER spread.

[4] Note that this is earlier than the beginning of the Phase II EUA spot trades. Spot trading started in February 26th 2008 due to the fact that Phase II EUAs were only physically available after the beginning of that phase in January 2008.

buyer's account.[5] Thus, ICE Clear Europe acts as a central counterparty to all trades and guarantees the financial performance of the ICE Futures Europe contracts registered in the name of its Members. [6]

It is important to consider that EUAs have not been clearly classified in the literature as commodities or financial assets. They present some features of financial assets such as storability (as carbon markets are organized by accounts transactions EUAs do not present storage problems). However, Benz and Trück (2006) pointed out that while the value of a stock is based on profit expectations of the firm, this is not the case of the EUA price. In the latter case, the prices are determined directly by the expected market scarcity provoked by factors such as energy prices and climate variables, as noted by Mansanet-Bataller et al. (2007) and Alberola et al. (2008). In this sense, the EUAs are closer to the commodities behaviour. This is the idea defended by Borak et al. (2006) that classed the EUAs as a new commodity that companies, under the 2003/83/EC Directive, need in order to carry out their activity. Borak et al. (2006) pointed out that EUAs can be considered as "*operating materials that are directly linked to a production system*". With that said, there is an important difference between operating materials and EUAs. On the 30th of April of the following year, installations need to surrender the same amount of allowances than their real emissions from the previous year. Thus, the installations only need to have in their electronic inventories the allowances that correspond to their verified emissions of a specific year, on this precise date (2003/87/EC Directive). Furthermore, Medina-Martinez and Pardo (2010) analysed the statistical properties of Phase II EUA returns. Their results show that returns on Phase II EUAs present the majority of the phenomena observed in commodity futures (such as heavy tails, volatility clustering, asymmetric volatility and the presence of a high number of outliers) but also statistical properties typical of financial assets (negative asymmetry and absence of an inflation hedge). Thus, concluding that returns on Phase II EUAs do not behave like other typical commodity futures.

Finally, it is important to underline that companies covered by the 2003/87/EC Directive (the large CO_2 emitting installations) are not the only participants that are able

[5] The delivery period is the period beginning at 6:00 pm on the contract date and ending at 7:00 pm on the second business day following the relevant contract date. There is provision for 'Late' and 'Failed' delivery within the contract rules.
[6] Please see http://www.ecx.eu/uploads/pdf/eua%20daily%20futures%20contract%20specs.pdf for more information on margin and payment (22 September 2010).

to take part in the EU ETS. Every natural and legal person is authorized to open an account and participate in this emissions trading scheme. Thus, it is important to study the existence of new investment opportunities, not only for installations covered under the EU ETS, but also for those participants that do not have emission reduction targets. However, the descriptive statistics of Phase II EUAs will be analysed before examining the diversification opportunities that may arise when including CO_2 assets in traditional portfolios.

In Table 1, the mean, the variance, the standard deviation, the maximum, the minimum, and the Sharpe ratio of weekly returns of ECX EUA December front futures prices of Phase II from April 22nd 2005 to November 3rd 2010 are presented in order to analyse the performance of Phase II EUAs.

[Please, insert Table 1].

One can observe that the weekly historical returns of Phase II EUAs prices presented a negative mean (an annual average loss of 2.14 %), a relatively high standard deviation and thus a negative but near to zero Sharpe ratio.[7] In relation to the returns' mean it is important to take into account that the sample period considered runs from 2005 to 2010 and thus includes the financial crisis that started August 1st 2007 with the first cut in interest rates by the U.S. Federal Reserve. As pointed out by Mansanet-Bataller et al. (2011), Phase II EUAs where used during this sample period as a way of obtaining liquidity. As the installations under the EU ETS only need to surrender the EUAs on April 30th the year after the emissions took place, selling the EUAs was, during the liquidity crisis, a cheap way of obtaining cash. Those massive sales jointly with the reduction of the European CO_2 emissions provoked by the economic crisis explain the Phase II EUAs negative mean returns.

Additionally, the evolution of the volatility of those prices during the sample period considered is shown in Figure 4. Each point depicts a moving annualized standard deviation for the previous 20 prices (19 returns).

[Please, insert Figure 4].

[7] Note that other authors such as Choueifaty and Coignard (2008) also find, for their portfolio that represents the market cap-weighted benchmark and the equally weighted one, negative Sharpe ratios during the period 2001-2008.

One can discern that the annualized volatility has considerably decreased since the start of the EU ETS. However, the previous results suggest that investing (buying) in this asset would be very risky, with negative expected return, and consequently not recommended.

3. DATA AND ANALYTICAL FRAMEWORK

For the purpose of this paper, the most representative series of carbon prices are used to analyse the benefits of investment opportunities for a European investor that includes carbon assets in diversified portfolios. Considering the above mentioned findings, the Phase II EUA front futures December contracts prices traded on the European Climate Exchange (ECX) have been selected.

Moreover, we have considered the most representative data referred to equities, fixed income and commodities all of them obtained from Reuters Database. Specifically, we have used the Dow Jones Euro Stoxx 50 index to represent the stocks, and the Iboxx index as representative of corporate bonds. As Phase II of the EU ETS comprises five years (from 2008 to 2012), we have considered the five-year Federal German notes (Bobls) as a representation of fixed income securities. In relation to commodities, following Jensen et al. (2002), we have taken into account the Goldman Sachs Commodity Index (GSCI). This index is also published in sub-indexes. Therefore the global GSCI and the Energy GSCI sub-index have been considered in separate portfolios. Note that comparable data that allows one to create portfolios that may be replicable have been used.

In order to take into account that the CO_2 prices considered are not an index as they are the rest of the variables, we have performed our analysis also using the Société Géneral CO_2 index, an index comprised of 50% EUA and 50% CERs, which has been published since March 14th 2008. Two main reasons justify the final use of Phase II EUA front futures December contracts prices traded on the European Climate Exchange. Firstly, using this series for CO_2 increases considerable the sample period to be analysed and secondly, the results are very similar independently of which series is used.[8]

Finally, in order to perform the analysis and especially to obtain the Sharpe ratio for the different assets, the EONIA has been considered as the risk-free interest rate of returns.

Our sample period starts with the beginning of Phase II EUA trading and thus runs from April 22nd 2005 to November 3rd 2010.

Note that the series in levels that were not stationary, have been converted into stationary returns taking first logarithm differences. That is, the study has been carried out by using continuous compounded returns constructed as $r_{c,t} = ln(P_{i,t} /P_{i,t-1})$ where $P_{i,t}$ is the level of the variable *i* at time *t*. The mean-variance analysis will be performed using weekly returns data. For this reason, once we have obtained the daily returns we calculate the weekly returns for all assets as the sum of a 5-day return moving window.[9]

Table 2 presents the descriptive statistics of all new data considered in the study. Specifically, we have obtained the mean, the variance, the standard deviation, the maximum and the minimum returns, and the Sharpe ratio. In all cases we have used historical weekly returns.

[Please, insert Table 2]

As shown in Table 2, the historical returns of the variables considered in the study present mainly negative means, aside from the stocks returns and corporate bonds. This, as in the case of returns on Phase II EUA, may be explained by the financial crisis that hit financial markets as of August 2007. The asset that present the most negative returns are commodities, especially energy commodities (-8.84%). In regard to the individual risk of each asset, the results confirm that the assets presenting less risk (which have a lower standard deviation) are the fixed income assets (both sovereign and corporate bonds) and the ones presenting higher levels of risk are the commodities, especially energy commodities. The Euro Stoxx 50 presents a standard deviation of around 20% during the sample period of study.

In addition, Figure 5-A presents the annualized mean-standard deviation trade-off of the different assets considered in the study using weekly historical returns.

[Please, insert Figure 5]

Not surprising, the asset with higher annual returns and lower annual standard deviation

---

[8] Due to space limitations the results are not presented here but they are available upon request.
[9] Note that with this methodology the results obtained are very similar to the average of those obtained from weekly returns using as the starting day the 5 days of the week.

is the Iboxx index. The Euro Stoxx 50 is the other asset presenting positive returns but, as it has been observed, it presents a high standard deviation. The commodity index and Phase II EUA returns present not only negative returns but also high levels of standard deviation.

However, as noted by Elton et al. (1987) and Black and Litterman (1992), the historical returns provide poor guides to future returns. Additionally, Chopra and Ziemba (1993) pointed out that using forecast that do not accurately reflect the relative expected returns of different securities can substantially degrade the mean-variance performance. Nevertheless, those authors used different forecasting schemes, apart from historical returns, and their results continued to hold as long as the inputs had errors. Additionally, they find that the errors in means, variances, and covariances depend on risk aversion but in all cases the consequences in terms of cash equivalent loss are higher for errors in the mean forecast.

To further examine this problem, when performing the mean variance analysis, the expected returns of the assets considered in this study have been obtained, following Karavas (2000), using a return forecast model that assumes all assets have the same risk-adjusted return (Sharpe ratio). That is, we have conducted a cross-sectional non parametric regression of historical return on historical standard deviation for all the assets included in the study. We have determined the common Sharpe ratio and we have obtained the expected returns for each asset imposing the fixed Sharpe ratio for all assets. Using this methodology, only the level of the return and not the time series properties are adjusted, and thus, this approach preserves the variance of the asset as well as the correlation with all other assets.[10] As shown in the last row of Table 1 and Table 2, the risk-adjusted expected return of all assets considered in the study is positive.

Figure 5-B presents the return-standard deviation trade-off of the assets considered in the study using risk-adjusted returns. The results differ slightly from those obtained using historical returns that were presented before. As previously observed, the standard deviation is the same independently of the methodology used but in this case all the

[10] The choice of the non-parametric methodology in order to obtain the common Sharpe ratio is principally due to the few data available for the cross-sectional analysis. In this case, the estimated values are the medians of the conditional distribution of the independent variable (the historical returns of the assets) instead of the means.

expected returns are positive.

In the next section, the effects of including Phase II EUAs in already diversified portfolios will be analysed applying the mean-variance methodology of Markowitz (1952) using both the expected historical and risk-adjusted returns.

4. EFFECTS OF INCLUDING PHASE II EUAS IN ALREADY DIVERSIFIED PORTFOLIOS

To analyse the impact of including Phase II EUAs in diversified portfolios, the hypothesis that the investor only has the possibility to invest in traditional investment assets (stocks and bonds), commodities (either the global GSCI or the energy specific GSCI sub-index), and Phase II EUAs has been undertaken.

By analysing the effects of introducing Phase II EUAs in portfolios presenting different combinations of assets, and particularly by distinguishing the portfolios with and without energy commodities, two different types of investors that participate in the EU ETS are taken into account. In the first group, the investors that do not have carbon reduction obligations and thus their diversified portfolio may or not include energy variables. The second group of investors consists of companies with carbon reduction targets that most likely already have energy variables in their portfolios. Note that this type of investors is not only interested in diversifying the portfolio but they may also hedge the risk of CO_2 price variation. Specifically the six portfolios described in Table 4 have been considered.

[Please, insert Table 4]

That is, Portfolio I is made up of stocks and bonds, Portfolio II is formed by stocks, bonds, and Phase II EUAs, Portfolio III includes stocks, bonds, and global commodities, Portfolio IV consists of stocks, bonds, global commodities, and Phase II EUAs, Portfolio V is made up of stocks, bonds, energy commodities, and finally, Portfolio VI is comprised of stocks, bonds, energy commodities, and Phase II EUAs.

This distinction may also be useful in order to determine if Phase II EUAs are or are not a new asset class. As it has been pointed out, Medina-Martinez and Pardo (2010) conclude that there are substantial differences in the behaviour of EUAs and other commodity prices. If those differences were not too important, one would expect that the contribution of Phase II EUAs to the diversification of the portfolio including the energy variables would be minimal, and thus, this would be a new argument to include EUAs in the commodities asset class.

4.1. Correlation Analysis

One of the main conditions for the asset that is going to be introduced in a portfolio with the objective to increase the opportunity investor set, is that it has to present low or negative correlation with the assets already in the portfolio. In Table 3 the correlation analysis using weekly returns for the period from April 2005 to November 2010 between all assets taken into account in the study (Phase II EUA, German Bolb notes, Euro Stoxx 50, Iboxx index, global GSCI index, and energy GSCI sub-index) are presented.

[Please, insert Table 3].

Table 3 shows that Phase II EUAs present positive and statistically significant correlation with the Euro Stoxx 50 (correlation about 8%), the global GSCI and the energy GSCI sub-index (correlations about 22%). They present negative and statistically significant correlation with the Iboxx index (correlation about - 6%) and do not present statistically significant correlation with the German Bolb notes. Conversely, Iboxx index is negatively correlated with the other assets considered in the study besides the German Bolb notes. Likewise the Euro Stoxx 50 is positively correlated with the other assets in the study except the Iboxx index. Finally, the two indices of commodities are extremely positively correlated with each other (correlation of 98%).

Nevertheless, as pointed out by Statman and Scheid (2008), correlation is a common indicator of the benefits of diversification, but does not provide an intuitive measure of the benefits of diversification. They propose the return gap, defined as the difference between the returns of two assets, as a better indicator, and provide the expression to obtain the forecasted return gap as a function of the mean of the annualised standard deviation of the two assets and their correlation. The authors show that even in periods of high correlation between the assets, the benefits of diversification can be important as long as the standard deviations are elevated. As Phase II EUAs present a relatively high standard deviation, thus it is interesting to continue the analysis of the benefits of diversification of including this new asset in already diversified portfolios.

4.2. Mean Variance Analysis

In order to analyse the benefits of including Phase II EUAs in diversified portfolios, the optimal asset weights allowing for short sales for the six portfolios described in Table 4 have been obtained. That is, the efficient frontiers of the six different sets of assets are obtained using Markowitz (1952) mean-variance methodology.[11] Specifically, in line with the previous section, the variance of each portfolio has been minimized using two different sets of expected returns: (i) historical returns and (ii) risk-adjusted returns. As a result, the fact that the method used to obtain the expected returns is determinant on the results of the minimization problem is taken into account. In Figure 6-A (B) the results for the optimal portfolios obtained using historical (risk-adjusted) returns are presented.

[Please, insert Figure 6].

In Figure 6-A, the efficient frontiers for the six different combinations of assets are obtained using historical returns. As one can observe, in this case, there is no difference between the efficient frontier of Portfolio I and Portfolio II, Portfolio III and Portfolio IV and Portfolio V and Portfolio VI. That is, the opportunity set for a European investor that invests in traditional assets (stocks and bonds) is not substantially different to the opportunity set for the European investor that includes, a part form traditional assets, also Phase II EUAs. The same argument applies for the investor that includes traditional assets and commodities and the one that includes traditional assets and energy commodities in their portfolios. In all those cases the incorporation of Phase II EUAs does not increase the investor opportunity set. Note that the combination of assets that allow for a better trade-off between risk and returns is the one that includes a part form traditional investments, energy commodities. These results are coherent with the previous results presented throughout the article. The correlations

[11] The efficient frontiers are obtained using the Excel “solver” function.

of Phase II EUAs with the other assets that are already in the portfolios are considerably high. Additionally, Phase II EUAs is the asset that not only presents historical negative returns but has the highest standard deviation leading to the lowest asset Sharpe ratio in absolute terms. However, even if Phase II EUAs had a very high standard deviation compared to energy variables or to the traditional investment it do not present sufficiently high enough returns to be an attractive investment to be included in the portfolio.

In order to complete this analysis it would be interesting to know which of the assets are sold in the optimal portfolio, which of them are bought and in which proportions. With this purpose, the efficient weights of the assets in each portfolio have been obtained for three levels of annual return: 3%, 5% and 10%. That is, the weights of the asset that minimize the variance of the portfolio for these specific returns have been obtained. The results, shown in Figure 7, illustrate that for the three levels of return the most weighted asset for the six portfolio considered is corporate bonds, followed by the German Bolb notes and by the Euro Stoxx 50.

[Please, insert Figure 7]

This is coherent with the previous results and with the implications of the Markowitz (1952) methodology that overweight the assets with higher returns and lower standard deviation. As pointed out by Black and Litterman (1992), when using the mean-variance optimization models with no constrains in the optimal portfolio against shorting, it is common to find large long and short positions in the optimal portfolios. The weights of the Phase II EUAs are very small and this explains why the investor opportunity set does not increase when introducing Phase II EUA in diversified portfolios. Note that in this figure we can also appreciate which optimal portfolios offer the smaller standard deviation for the same return (3%, 5%, and 10%) and thus the position of the efficient frontiers in the return-standard deviation space. In this case one appreciates that the efficient frontiers are nearly the same, in coherence with Figure 6-A.

The same analysis has also been performed using risk-adjusted returns as the expected returns for the different assets. As shown in Figure 6-B, The results are slightly different. In this case, the inclusion of Phase II EUAs in different portfolios increases the investor opportunity set of Portfolio I and Portfolio III. That is, if the European investor only invests in traditional assets or traditional assets and commodities, lower returns would be obtained for the same level of risk than if Phase II EUAs were included in the portfolio. Nevertheless, the best efficient frontier, the combination of assets that allow for a higher return for the same level of risk, are still in line with Portfolio V, that is, investing in traditional assets and energy commodities without including Phase II EUAs is the best combination of assets. It is important to note that in this case, the expected risk-adjusted returns for all assets are positive while that the variances and covariances remain unchanged.

Again, the weights of the efficient portfolios have been obtained and are presented in Figure 8. In this case, the returns are adjusted to impose the same Sharpe ratio to all assets. As shown in Table 1 and in Table 2, those returns are very similar among assets and thus the criteria to include the asset in the portfolio with a positive or negative sign in this case, is principally the standard deviation that the asset introduces to the portfolio.

[Please, insert Figure 8]

As we can observe, the assets that present a high standard deviation are introduced in the portfolio with selling positions and those that present a low standard deviation with buying positions. Thus, only corporate bonds participate as long positions in the portfolio and the other assets as short positions. Those results are coherent with the fact that the mean-variance model tends to overweigh (underweigh) those securities that performed well (poorly) in the reference period of time. In this case the Phase II EUAs participate significantly in the portfolio and thus, when the risk-adjusted returns are considered as expected returns, the inclusion of Phase II EUA in the portfolio is pertinent as long as the portfolio manager takes a short position. Thus, Allowing for short selling is the only way of obtaining a participation of CO_2 in the portfolio.

5. Summary and Concluding Remarks

Trading of EUAs is possible, both OTC and in several European organized markets, since the launch of the EU ETS. However, it is important to distinguish between Phase I and Phase II EUAs because, as banking between those two phases was not allowed, their price evolution corresponded to supply and demand factors within each phase. As the interest in the EU ETS is constantly increasing and Phase I is already finished, this paper focuses its attention on the effects of including Phase II EUAs in diversified portfolios, in mean-standard deviation trade-off terms. The analysis comprises the period from April 22nd 2005 to November 3rd 2010 and uses the most representative price series for Phase II EUA, bonds (sovereign and corporate), stocks and commodities.

From the analysis of the specificities of the EU ETS the most important conclusions are that (i) the EU ETS is a recent and artificially created market to facilitate the commitments of the Kyoto Protocol, (ii) every natural or legal person with an account on the trading platform is eligible to trade EUAs and thus the interest for capital managers with knowledge of this new market is large, (iii) Phase II EUA prices are not expected to evolve toward prices near zero as in the case of Phase I EUAs because banking is allowed between Phase II and Phase III of the EU ETS, (iv) the most suitable carbon asset to be included in diversified portfolios is the Phase II EUA December front contract traded on ECX, and (v) Phase II EUAs are not clearly defined in the literature as commodities or financial assets (while they present most of the phenomena observed in commodity futures they also present statistical properties typical of financial assets).

Additionally, weekly historical returns of Phase II prices presented a negative mean and a high standard deviation, suggesting that investing in this asset on its own would not be recommended following the results of the sample period analysed. However, it is important to consider that this period was highly conditioned by the financial crisis and then the economic crisis that hit Europe since 2007. If we compare with the other assets considered in the study, only the corporate bonds and the Euro Stoxx 50 presented low but positive returns.

In what concerns the effects of including Phase II EUAs in already diversified portfolios, the Markowitz (1952) methodology has been used considering both historical and risk-adjusted returns in order to take into account that historical returns provide poor guides to future returns. Different portfolios have been built up with the objective to consider the different participants in the EU ETS. The results using historical returns show that the weights of Phase II EUAs are negligible and thus, the efficient frontier do not differ whether we consider or not the inclusion of Phase II EUA in the portfolios considered. However, when using risk-adjusted returns, taking a short position in Phase II EUAs increases the investor opportunity set.

6. REFERENCES

Alberola, E., Chevalier, J., and Chèze, B., 2008. "Price Drivers and Structural Breaks in European Carbon Prices 2005–2007". Energy Policy, 36(2), 787-797.

Benz, E., and Trück, S., 2006. "CO_2 Emission Allowances Trading in Europe – Specifying a new Class of Assets". Problems and Perspectives in Management, 4(3), 30-40.

Black, F. and Litterman, R., 1992. "Global Portfolio Optimization". Financial Analysts Journal. 48(5), 23-43.

Borak, S., Härdle, W., Trück, S., and Weron, R., 2006. "Convenience Yields for CO_2 Emission Allowance Futures Contracts". SFB 649 Discussion Paper 2006-076.

Chandrashekaran, V. 1999. "Time-Series Properties and Diversification Benefits of REIT Returns". Journal of Real Estate Research, 17(1/2).

Chopra, V. K., and Ziembra, W. T., 1993. "The Effect of Error in means, variances and Covariances on Optimal Portfolio Choice". Journal of Portfolio Management, 19(2), 6-11.

Choueifaty, Y., and Coignard, Y., 2008. "Toward Maximum Diversification". Journal of Portfolio Management, 35(1), 40-51.

Directive 2003/87/EC of the European Parliament and of the Council of 13 october 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending council directive 96/61/EC.

Elton, E. J., Gruber, M.J., and Rentzler, J.C., 1987. "Professionally Managed, Publicly Traded Commodity Funds". The Journal of Business, 60(2), 175-199.

Ellerman, A. D., Convery, F.J., and de Perthuis, C., 2010. "Carbon Pricing. The European Union Emission Trading Scheme". Cambridge University Press.

Erb, C. B. and Harvey, C.R., 2006. "The Strategic and Tactical Value of Commodity Futures". Financial Analysts Journal, 62(2), 69-97.

Eun, C. S. and Resnick, B.G., 1988. "Exchange Rate Uncertainty, Forward Contracts, and International Portfolio Selection". Journal of Finance 43 (1), 197-215.

Garrouste, F., Jones, D., Berthat, F., Anselmi, F., Carlat, T., 2010. "Finance Carbone. L'Europe, le Bastion de Résistence". AGEFI Hebdo, Tous les Métiers de la Finance, 241, 26-32.

Gorton, G. and Rouwenhorst, K., G., 2006. "Facts and Fantasies about Commodity Futures". Financial Analysts Journal, 62 (2), 47-68.

Grubel, 1968. “Internationally Diversified Portfolios: Welfare Gains and Capital Flows. The American Economic Review, 58(5), 1299-1314.

Ibbotson, R. G., and Siegel, L.B., 1984. “Real Estate Returns: A comparison with Other Investments”. AREUEA Journal, 12(3), 219-242.

Jensen, G. R., Johnson, R. R., and Mercer, J. M., 2002. “Tactical Asset Allocation and Commodity Futures”. Journal of Portfolio Management, 28 (4), 100-110.

Karavas, V. N., 2000. “Alternative Investments in the Institutional Portfolio”. Journal of Alternative Investments, 3(3), pp. 11–26.

Kuhle, J. L., 1987. “Portfolio Diversification and Return Benefits-Common Stock vs. Real Estate Investment Trusts (REITs)”. The Journal of Real Estate Research, 2(2), 1-9.

Mansanet-Bataller, M., Pardo, A. & Valor, E., 2007. “CO_2 Prices, Energy and Weather”. The Energy Journal 28, 73-92.

Mansanet Bataller, M and Pardo Tornero, A., 2008a. “CO_2 Prices and Portfolio Management”. Available at SSRN: http://ssrn.com/abstract=1156975 (January 10th 2011).

Mansanet-Bataller M., Pardo Á. 2008b. “What You Should Know About Carbon Markets”. *Energies*, 1(3), 120-153.

Mansanet-Bataller, M., Chevallier, J., Herve-Mignucci, M., and Alberola, E., 2011. “EUA and sCER phase II price drivers: Unveiling the reasons for the existence of the EUA–sCER spread”. Energy Policy (Forthcomming).

Markowitz, H., 1952. “Portfolio Selection”. The Journal of Finance, 7(1), 77-91.

Medina-Martinez, V., and Pardo, A., 2010. “Is the EUA a new asset class?”. University of Valencia Working Paper.

Statman, M., and Scheid, J., 2008. “Correlation, Return Gaps, and the Benefits of Diversification”. Journal of Portfolio Management, 34(3), 132-139.

Table 1: Descriptive Statistics of Assets Performance.

This table presents the mean, the variance, the standard deviation, the minimum (Min), and the maximum (Max), and the Sharpe ratio of Phase II EUA December Front Futures contract traded at ECX using weekly historical returns, for the sample period from April 22nd 2005 to November 3rd 2010. All results except the minimum and the maximum (that are in percentages) and Sharpe ratio are annualized and presented in percentages. The last row shows the risk-adjusted expected return.

	Phase II EUA
Mean	- 2.14
Variance	1850.46
Standard Deviation	43.02
Min	- 49.85
Max	22.52
Sharpe ratio	-0.0135
Risk - Adjusted Expected Return	1.49

Table 2: Descriptive Statistics of Asset Performance.

In this table, the mean, the variance, the standard deviation, the minimum (Min) and the maximum (Max), and the Sharpe ratio of the assets considered in the study are shown using weekly historical returns, for the sample period from April 22nd 2005 to November 3rd 2010. All results except the minimum (Min) and the maximum (Max), presented in percentages, and the Sharpe ratio are annualized and presented in percentage. The last row shows the risk-adjusted expected returns.

	German Bobl	Iboxx	Euro Stoxx 50	GSCI Global	GSCI Energy
Mean	-0.22	3.04	1.83	-4.56	-8.84
Variance	28.05	10.73	412.46	624.20	966.21
Standard Deviation	5.30	3.28	20.31	24.98	31.08
Min	-8.30	-3.41	-16.92	-15.61	-18.58
Max	4.29	1.76	12.25	15.14	20.83
Sharpe ratio	-7.73	10.19	-0.03	-1.04	-1.12
Risk - Adjusted Expected Return	1.94	1.95	1.85	1.79	1.71

Table 3: Correlation Analysis among Assets.

This Table presents the correlation of the weekly returns among all assets considered in the study, for the sample period from April 22nd 2005 to November 3rd 2010. The critical value for the statistical significance of the correlations coefficient is calculated as $2/n^{1/2}$. * indicates the coefficients are statistically significant at the 5% level.

	Phase II EUA	German Bobl	Iboxx	Euro Stoxx 50	GSCI Global
German Bobl	-0.02901	1.00000*			
Iboxx	-0.06432*	0.40525*	1.00000*		
Euro Stoxx 50	0.08779*	-0.25455*	-0.11844*	1.00000*	
GSCI Global	0.23739*	-0.16076*	-0.14615*	0.39856*	1.00000*
GSCI Energy	0.22166*	-0.15343*	-0.15071*	0.36830*	0.98632*

Table 4: Portfolio Components Description.

This Table presents the composition of the portfolios considered in the study. Portfolio I is made up of stocks, and sovereign and corporate bonds, Portfolio II is made up of stocks, sovereign and corporate bonds, and Phase II EUAs, Portfolio III is made up of stocks, sovereign and corporate bonds, and commodities, Portfolio IV is made up of stocks, sovereign and corporate bonds, Phase II EUAs, and commodities, Portfolio V is made up of stocks, sovereign and corporate bonds, and energy commodities, and finally, Portfolio VI is made up of stocks, sovereign and corporate bonds, energy commodities, and Phase II EUAs.

	German Bobl	Iboxx	Euro Stoxx 50	Phase II EUA	GSCI Global	GSCI Energy
Portfolio I	✓	✓	✓			
Portfolio II	✓	✓	✓	✓		
Portfolio III	✓	✓	✓		✓	
Portfolio IV	✓	✓	✓	✓	✓	
Portfolio V	✓	✓	✓			✓
Portfolio VI	✓	✓	✓	✓		✓

Figure 1: Phase I and Phase II EUA Price Evolution.

Figure 1-A shows the evolution of Phase I and Phase II EUA spot prices of contracts traded at BlueNext. All prices are presented in Euros per tonne.

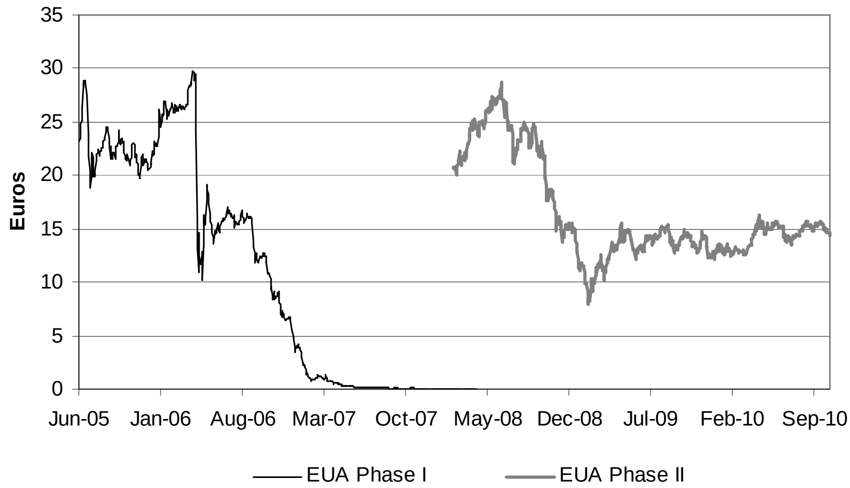
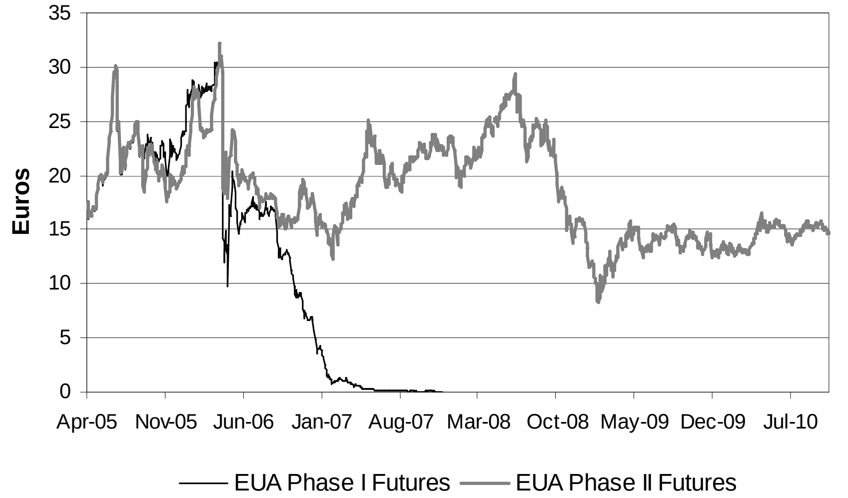


Figure 1-B shows the evolution of Phase I and Phase II EUA futures prices of contracts traded at ECX. All prices are presented in Euros per tonne.



Source: BlueNext and ECX.

Figure 2: Phase II EUA and CER Volume Analysis.

Figure 2-A shows the evolution of Phase II EUA and CER volumes traded in the EU ETS throughout organized markets since its beginning of the EU ETS to the 3rd November 2010.

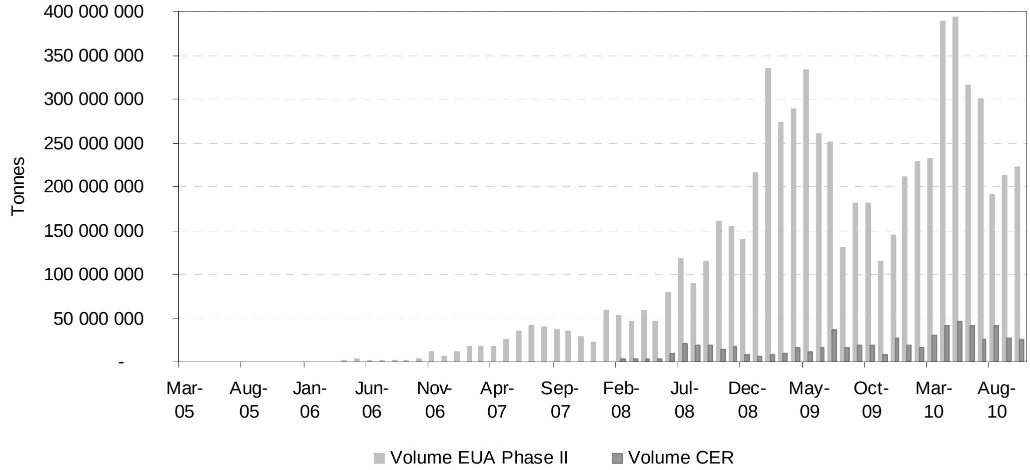


Figure 2-B shows the evolution of the volumes of the most important contracts traded at the EU ETS all market places and OTC deals considered. Spot is the total volume of the spot contracts, Dec 08, Dec 09, Dec 10, Dec 11, Dec 12 and Dec 13 are the total volumes of the Futures contracts with delivery in December of the indicated year.

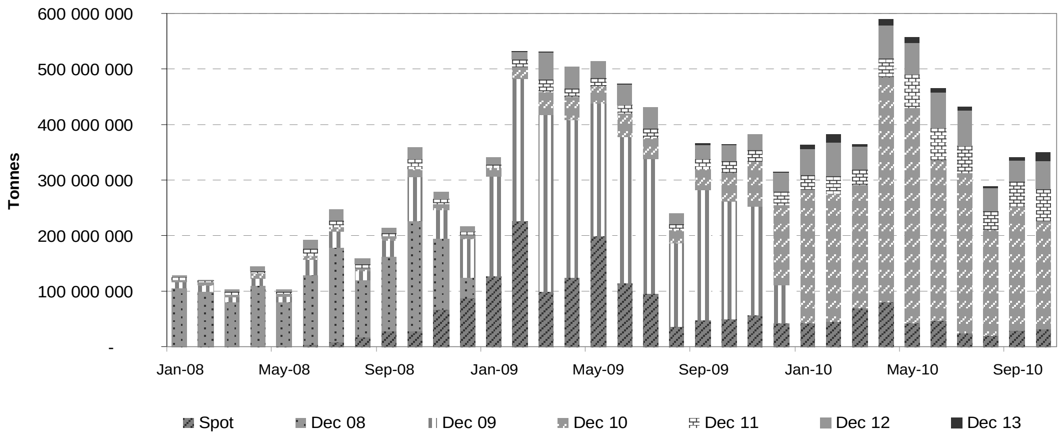
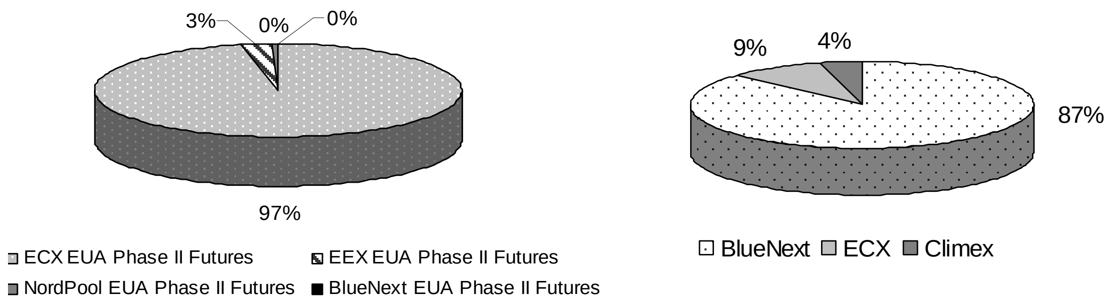


Figure 2-C shows in the left (right) the percentage of the total volume of the EUA Futures (spot) contracts traded in the most important marketplaces, by marketplace.



Source: CDC Climat

Figure 3: Phase II EUA and CER Prices Evolution.

Figure 3-A shows the evolution of the most important EUA prices traded in organized markets. BlueNext EUA Phase II spot are the spot prices of the EUA traded at BlueNext, EEX (BlueNext, ECX, and NordPool) EUA Dec 2010 Futures are the futures prices of the EUA contract with delivery in December 2010 traded at EEX (BlueNext, ECX, and NordPool), respectively. All prices are expressed in Euros per tonne.

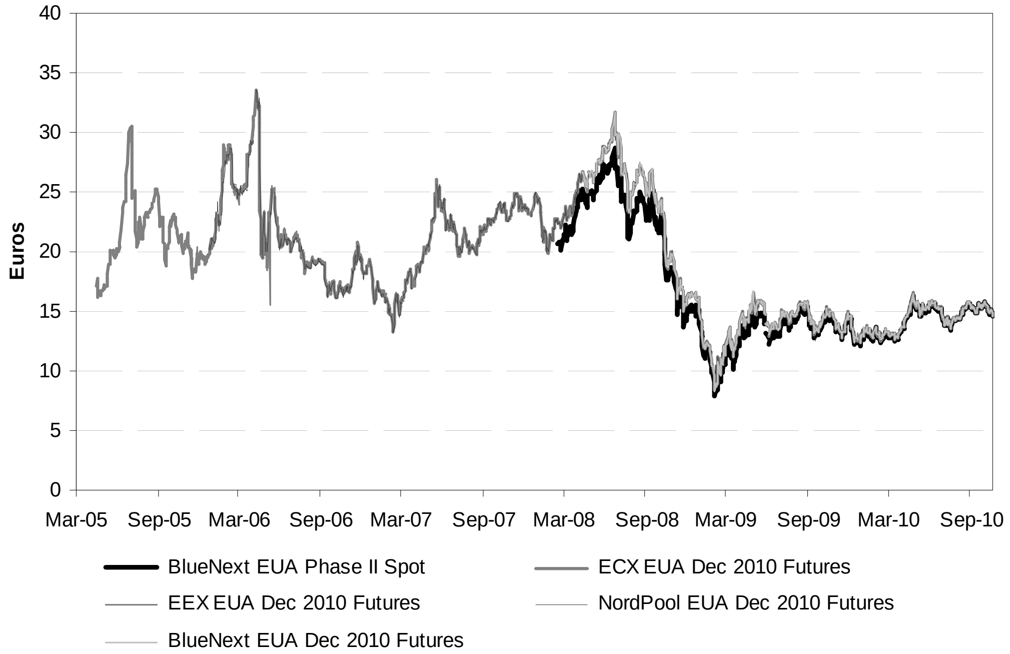


Figure 3-B shows the evolution of ECX EUA and ECX CER futures prices both with delivery in December 2010 for the sample period from 22nd April 2005 to 29th October 2010. Both prices are expressed in Euros per tonne.

Source: CDC Climat

Figure 4: Volatility Evolution.

This figure shows the evolution of Phase II EUA returns volatility. A moving standard deviation of 20 day sample is presented for the period from 22nd April 2005 to 3rd November 2010. The results are very similar if we consider sample periods of 10 and 5 weeks.

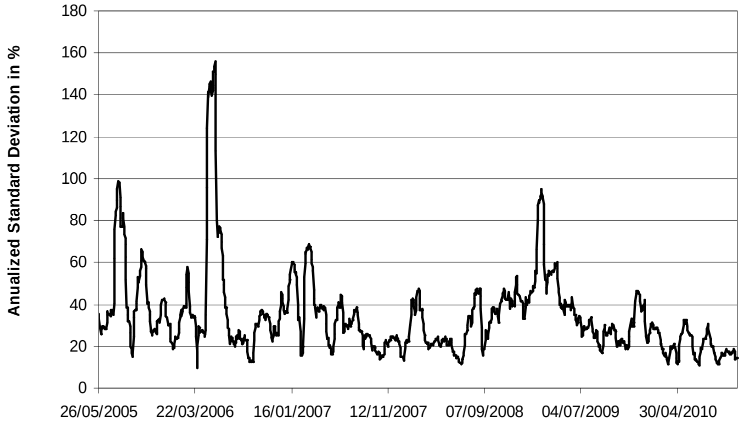


Figure 5: Asset Return-Standard Deviation Trade-Off.

Figure 5-A shows the Return and Standard Deviation Trade-off of the assets considered in this study using historical returns. Figure 5-B shows the Return and Standard Deviation Trade-off of the assets considered in this study using risk-adjusted returns.

Figure 5-A: Assets Return and Standard Deviation Trade-off with Historical Returns.

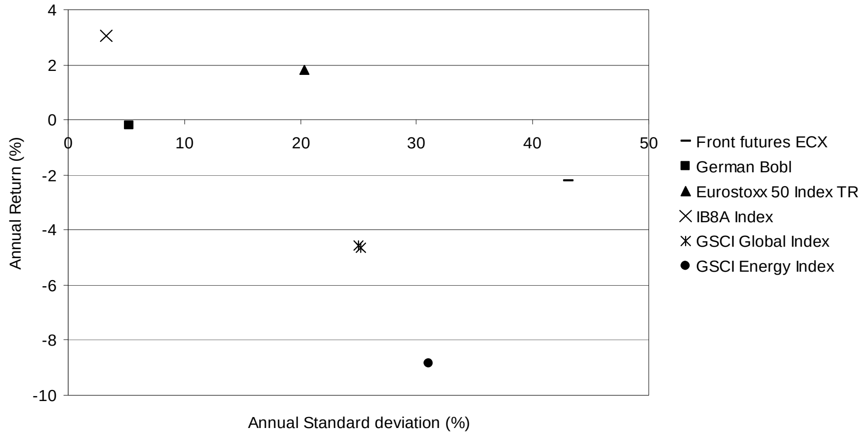


Figure 5-B: Assets Return and Standard Deviation Trade-off with Risk-Adjusted Returns.

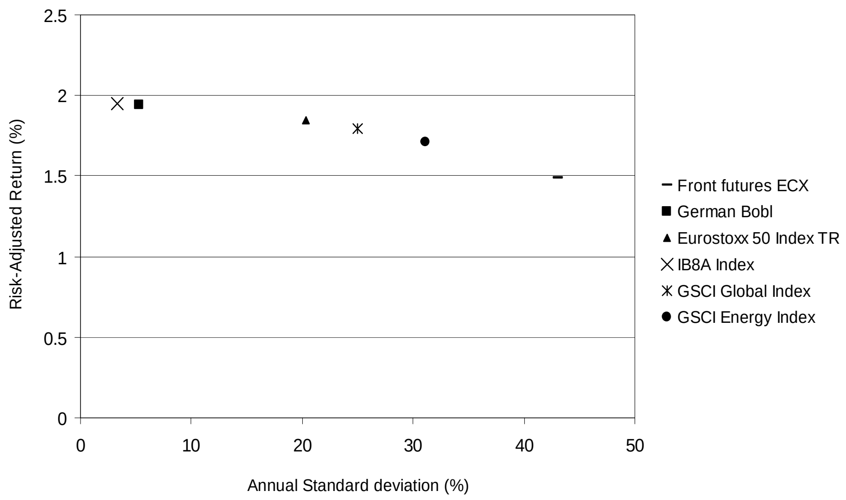


Figure 6: Efficient Frontier for the Different Portfolios Considered.

Figure 6-A (B) shows the efficient frontier for the six portfolios considered in the study using historical (risk-adjusted) returns. Portfolio I is made up of stocks, and sovereign and corporate bonds, Portfolio II is comprised of stocks, sovereign and corporate bonds, and Phase II EUAs, Portfolio III consists of stocks, sovereign and corporate bonds, and commodities, Portfolio IV is made up of stocks, sovereign and corporate bonds, Phase II EUAs, and commodities, Portfolio V is formed by of stocks, sovereign and corporate bonds, and energy commodities, and finally, Portfolio VI is comprised of stocks, sovereign and corporate bonds, energy commodities, and Phase II EUAs.

Figure 6-A: Efficient Frontier for the six Portfolios Considered. Historical Returns.

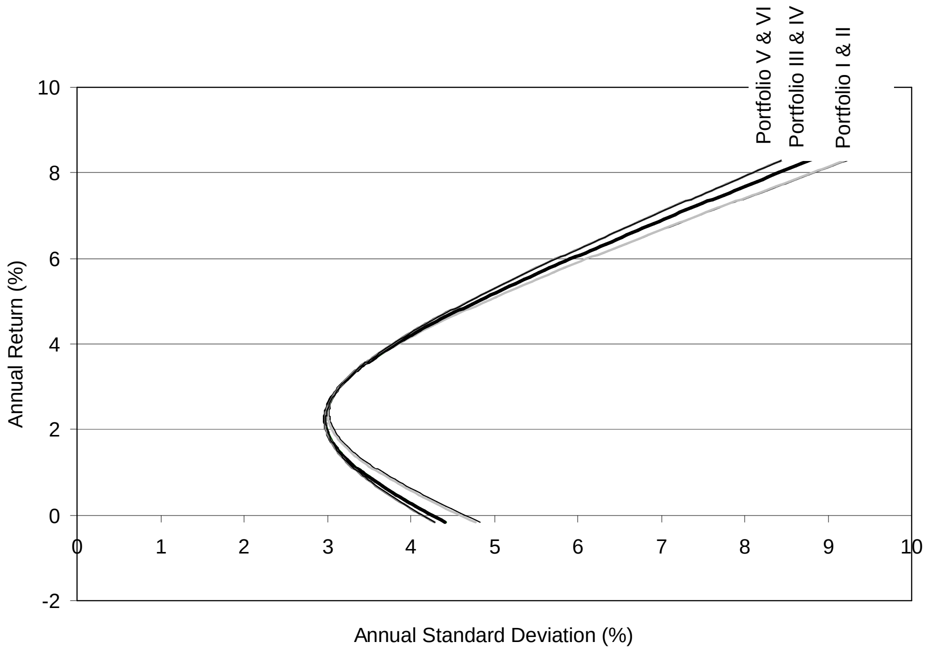


Figure 6-B: Efficient Frontier for the six Portfolios Considered. Risk-Adjusted Returns.

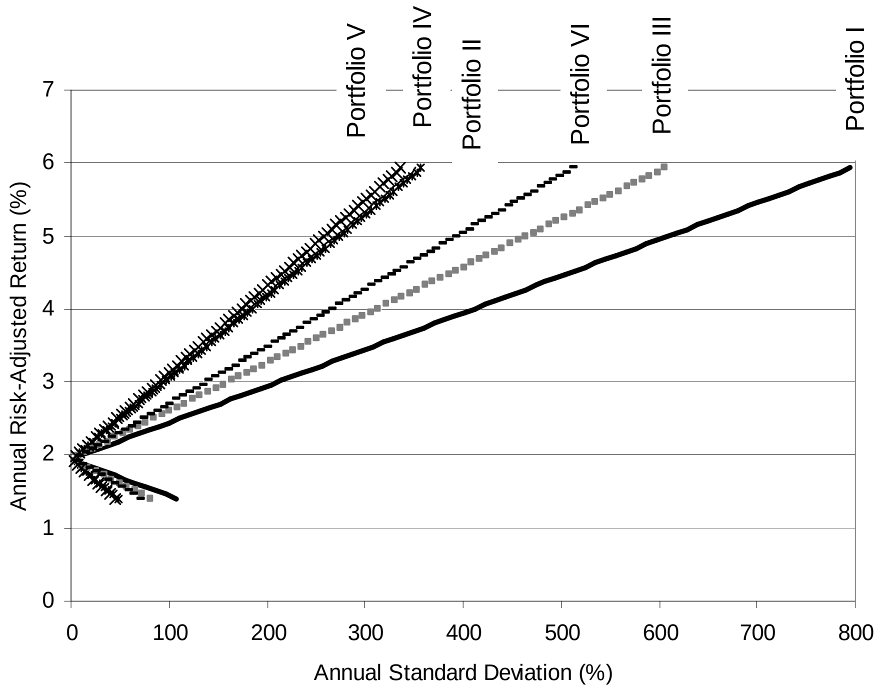


Figure 7: Assets Weights in the Efficient Frontier Portfolios. Historical Returns.

This figure shows the optimal asset weights of each asset in each of the six portfolios analysed in this study. Portfolio I is made up of stocks, and sovereign and corporate bonds, Portfolio II is comprised of stocks, sovereign and corporate bonds, and Phase II EUAs, Portfolio III consists of stocks, sovereign and corporate bonds, and commodities, Portfolio IV is made up of stocks, sovereign and corporate bonds, Phase II EUAs, and commodities, Portfolio V is formed by of stocks, sovereign and corporate bonds, and energy commodities, and finally, Portfolio VI is comprised of stocks, sovereign and corporate bonds, energy commodities, and Phase II EUAs. All the Panels show the results using Historical Returns.

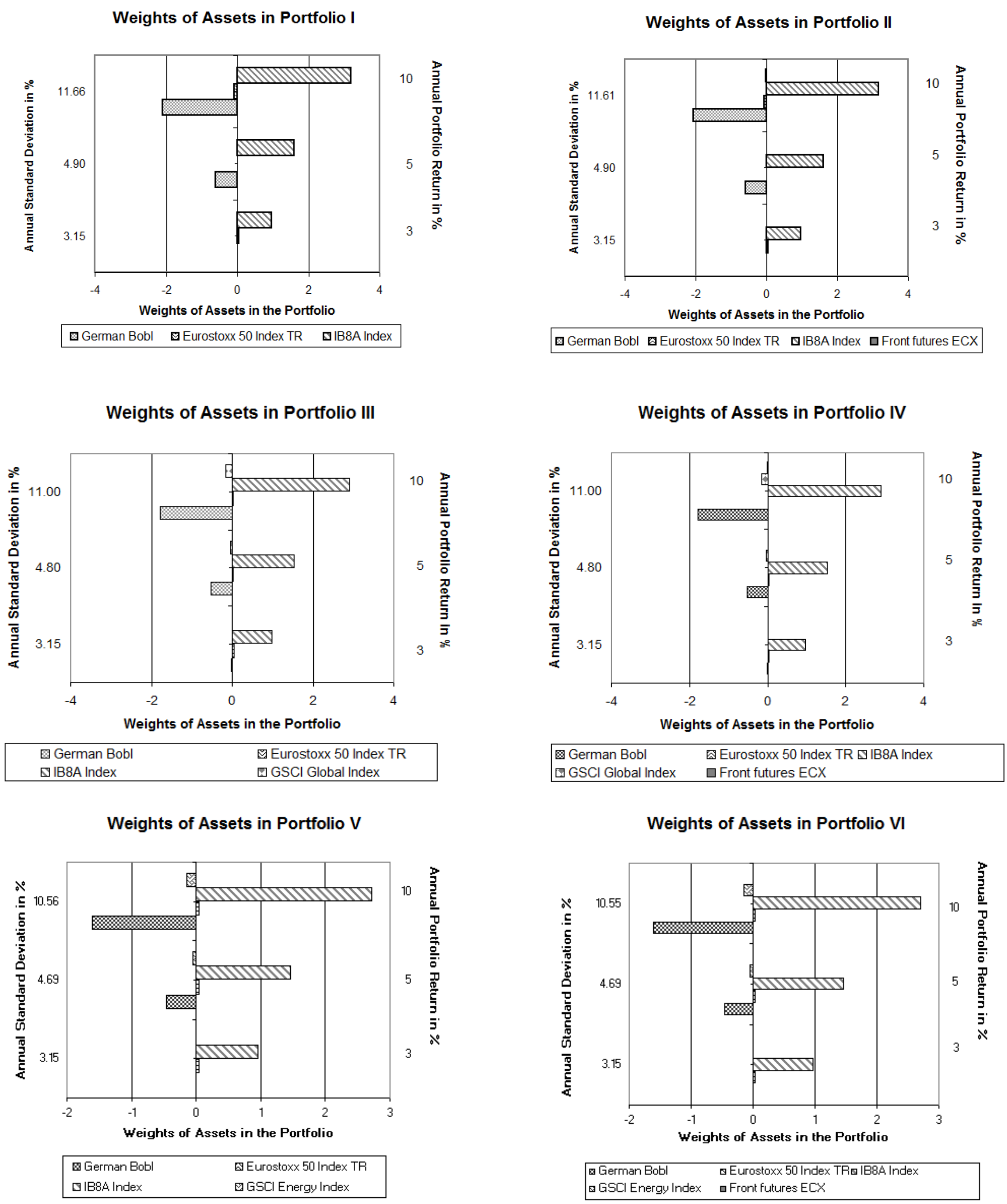
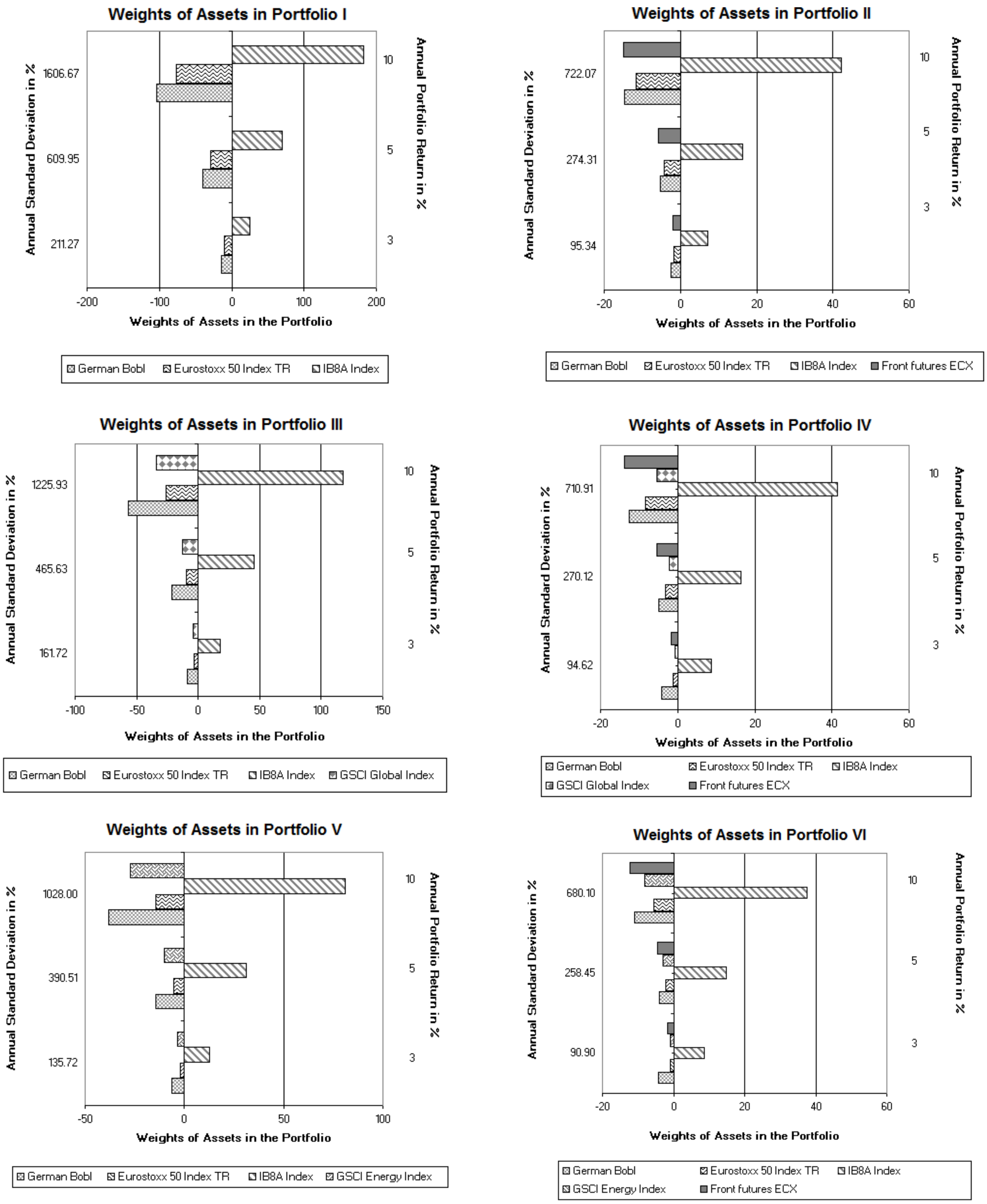


Figure 8: Assets Weights in the Efficient Frontier Portfolios. Risk-Adjusted Returns.

This figure shows the optimal asset weights of each asset in each of the six portfolios analysed in this study. Portfolio I is made up of stocks, and sovereign and corporate bonds, Portfolio II is comprised of stocks, sovereign and corporate bonds, and Phase II EUAs, Portfolio III consists of stocks, sovereign and corporate bonds, and commodities, Portfolio IV is made up of stocks, sovereign and corporate bonds, Phase II EUAs, and commodities, Portfolio V is formed by of stocks, sovereign and corporate bonds, and energy commodities, and finally, Portfolio VI is comprised of stocks, sovereign and corporate bonds, energy commodities, and Phase II EUAs. All the Panels show the results using risk-adjusted returns.



Working Paper Series

n° 2011-01

n° 2011-01 — **CO_2 Prices and Portfolio Management during Phase II of the EU ETS**
by Maria Mansanet-Bataller

n° 2 • November 2010 — **Public and private risk sharing in the financing of low- emitting urban infrastructure projects: the case of CDM projects in the waste sector**
by Dorothee Teichmann

n° 1 • June 2010 — **A two-sector model of the European Union Emissions Trading Scheme?**
by Suzanne Shaw

Contact us :
Chaire Economie du Climat - Palais Brongniart (4e étage)
28 Place de la Bourse, 75 002 Paris
Tel : +33 (0)1 49 27 56 34
Fax : +33 (0)1 49 27 56 28
Email : contact@chaireeconomieduclimat.org

Working Papers Publication Director: Pierre-André Jouvet
Les opinions exposées ici n'engagent que les auteurs. Ceux-ci assument la responsabilité de toute erreur ou omission

La Chaire Economie du Climat est une initiative de CDC Climat et de l'Université Paris-Dauphine sous l'égide de la Fondation Institut Europlace de Finance

Climate Economics Chair
Paris-Dauphine University
CDC Climat