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Facultat d'Economia, Departament d'Economia Financera i Actuarial

and

UNIVERSITÉ PARIS-DAUPHINE

Centre de Géopolitique de l'Énergie et des Matières Premières
École Doctorale Économie des Organisations : Concurrence, Innovation, Finance

ESSAYS ON CO_2

Dissertation presented by:
Maria Mansanet Bataller

Supervised by:

Ángel Pardo Tornero, Catedràtic d'Economia Financera (Universitat València)
Jan Horst Keppler, Professeur Agrégé d'Économie (Université Paris-Dauphine)

València, 2008.

Acknowledgements

I would like to start by thanking Ángel Pardo for taking on the risk of directing this dissertation, for encouraging me to engage in a profound study of the carbon markets, and in particular for his unlimited support, his guidance and advice.

I would also like to thank Enric Valor for his collaboration on the second chapter of this dissertation and all members of the Financial Economics Department at Universitat de València for the excellent working conditions and personal support they provided. Special thanks to Vicente Meneu for giving me confidence, and to Maria Dolores Furió who has become a real friend.

I am also grateful to Jan H. Keppler for allowing me to join the Centre for Geopolitics of Energy and Raw Materials at the University Paris Dauphine as a Ph.D. student and for agreeing to co-direct this thesis.

I would like to express my gratitude to Gabriel Foix (Bank of Valencia), Frank Kartmann (EEX), Magdalena Nowakowska (Nord Pool), Gabriel Paulik (Repsol YPF), Francisco Javier Población (Bank of Spain), and Sara Stahl (ECX) for providing the necessary data to perform this study, and Ignacio Gistau (Unión Fenosa) and several anonymous referees for their helpful suggestions and comments that improved considerably the quality of this dissertation.

I would like to thank the financial support of the Ministerio de Educación y Ciencia (reference number REN2003-08871 and CGL2006-06367/CLI), the FEDER, the Cátedra Finanzas Internacionales-Banco Santander and the Fundación Ramón Areces.

Finally, I am deeply grateful to my family and friends for supporting me throughout this dissertation. A special thank you to Lili for her understanding and encouragement, and to Anthony for his patience and unwavering support.

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RESUMEN

En los últimos tiempos, la importancia que el cambio climático tiene en nuestra sociedad está aumentando de forma continuada. En su último informe de síntesis publicado en 2007 y titulado "Cambio Climático 2007: Informe de Síntesis", el Panel Intergubernamental sobre el Cambio Climático (IPCC en sus siglas en inglés) advierte que no hay ninguna duda acerca de las causas antropogénicas del cambio climático. En este mismo informe urge a los gobiernos a que encuentren una solución a uno de los problemas más importantes del siglo XXI.

Una de las respuestas que ha generado tanto la necesaria mitigación del cambio climático como la adaptación a sus consecuencias más inmediatas, ha sido la aparición de un nuevo concepto en las sociedades modernas: las Finanzas del Carbono (o ***Carbon Finance***). Según Labatt and White (2006) la Carbon Finance explora las implicaciones financieras de vivir en un mundo sujeto a la limitación de las emisiones de dióxido de carbono y de otros gases de efecto invernadero, donde dichos gases tienen un precio. Los mercados de carbono son una parte importante de la Carbon Finance, pero no la única. El desarrollo de proyectos para reducir las emisiones de gases de efecto invernadero (nuevas oportunidades de estrategias de inversión alternativas) o las políticas gubernamentales cuyo objetivo es reducir las emisiones de dichos gases o facilitar la adaptación a los efectos del cambio climático, son otros de los pilares básicos de la Carbon Finance.

El informe Stern (2006) también señala la necesidad de establecer un precio para las emisiones de gases de efecto invernadero. Según dicho informe, para poder articular una

respuesta efectiva, eficiente y equitativa frente al cambio climático, es necesario disponer de señales de precio y por lo tanto disponer de mercados de carbono.

La aparición y la formación del precio del carbono ha sido posible, entre otras cosas, gracias a una de las políticas globales más importantes para reducir las emisiones de gases de efecto invernadero a nivel mundial: el Protocolo de Kyoto. Dicho protocolo entró en vigor el 16 de febrero de 2005. En él se fijan de forma legalmente vinculante objetivos de reducción de emisiones para los países industrializados que lo han ratificado. Dichas reducciones se deben producir durante el periodo 2008-2012. No obstante, existen tres mecanismos de flexibilidad que facilitan a los países sujetos al protocolo el cumplimiento de sus objetivos.

Entre dichos mecanismos se encuentra la negociación de emisiones (artículo 17 del protocolo de Kyoto), que ha jugado un papel crucial en el lanzamiento del mercado de emisiones europeo (EU ETS, en sus siglas en inglés). Según Lowrey (2006), a pesar de que los objetivos principales del EU ETS son (i) la reducción de emisiones de CO_2, (ii) la promoción de tecnologías poco intensivas en carbono y (iii) la eficiencia energética, posiblemente, el objetivo más importante es el establecimiento de un precio de mercado para los permisos de emisión. El establecimiento de dicho precio significa que las instalaciones europeas más emisoras de CO_2 son conscientes de las consecuencias financieras de sus actividades contaminantes.

El EU ETS, es el mercado financiero con fines medioambientales más importante del mundo. Si lo comparamos con el mercado americano de SO_2, el EU ETS incluye un mayor número de instalaciones; además, la cantidad de emisiones cubiertas en el esquema así como el valor de los activos creados y distribuidos es superior. Bajo este esquema, lanzado el 1 de enero de 2005, las instalaciones europeas que producen una cantidad importante de emisiones de CO_2 reciben de sus gobiernos, a través de los Planes Nacionales de Asignación (NAPs en sus siglas en inglés), permisos de emisión para cada una de las fases del EU ETS (Fase I y Fase II). La Fase I, considerada una fase piloto, incluye los años 2005-2007 mientras que la Fase II coincide con el periodo de cumplimiento del protocolo de Kyoto y, por lo tanto, incluye los años 2008-2012. Los permisos de emisión reciben el nombre de Permisos de Emisión Europeos (EUAs en sus siglas en inglés) y permiten emitir una tonelada de CO_2 en un país de la Unión Europea. Gracias al EU ETS, los permisos recibidos, los EUAs, pueden negociarse en varios mercados al contado, de futuros e incluso de opciones, siempre que las instalaciones cumplan con sus objetivos de reducción de emisiones en el plazo previsto.

El estudio de los mercados de carbono forma parte de las inquietudes del campo de las finanzas. Prueba de ello es que, desde el lanzamiento del EU ETS, el número de artículos académicos que se interesan por este tipo de mercados ha experimentado un incremento considerable. Sin embargo, al comienzo de esta tesis (septiembre 2005), no existían artículos de investigación que estudiasen empíricamente el comportamiento financiero de los mercados europeos de CO_2. Por lo tanto, uno de sus objetivos principales es enriquecer la literatura financiera en este campo.

Esta tesis se organiza en cuatro capítulos. Cada uno analiza el mercado europeo de CO_2 desde un punto de vista distinto.

CAPÍTULO 1: La negociación de CO_2

En concreto, el **primer capítulo** se titula "***La negociación de CO_2***" y el principal objetivo es describir el estado de la cuestión de los mercados de permisos de emisión. Desde la ratificación del protocolo de Kyoto por un gran número de países, la negociación de permisos de emisión se ha desarrollado de forma contínua y, por lo tanto, existe un interés creciente por estudiar este fenómeno.

Sin embargo, para centrar la cuestión en el mercado de permisos de emisión, empezamos este capítulo por los orígenes de la negociación de dichos permisos a nivel europeo. En primer lugar introducimos el protocolo de Kyoto y el mercado de emisiones como uno de los tres mecanismos de flexibilidad que permiten ayudar a los países firmantes del protocolo a alcanzar sus objetivos de reducción de emisiones. En este capítulo se explican cuales son las diferentes posibilidades de las que disponen los países que han firmado el protocolo de Kyoto, para alcanzar sus objetivos particulares. Además, se proporciona una descripción detallada de los objetivos por países y del estado de cumplimiento de los mismos, prestando especial atención a los países europeos.

Por otra parte, se contempla el hecho de que con anterioridad al lanzamiento del EU ETS, ha habido varias experiencias de negociación de permisos de emisión en diversas partes del mundo. Sin embargo, el EU ETS es, a día de hoy, y como se ha dicho anteriormente, el mercado más amplio a nivel mundial en el que se pueden negociar permisos de emisión de gases de efecto invernadero. Por lo tanto es importante comprender su funcionamiento así como su articulación y organización.

Para ello, una descripción detallada del EU ETS se proporciona en este capítulo. En esta descripción se consideran todos los aspectos tratados en la directiva europea que regula este mercado (2003/97/CE) y se intenta dar una visión lo más amplia posible de dicho mercado. Los temas tratados incluyen los sectores europeos sujetos a la directiva, los Planes Nacionales de Asignación y su importancia en el desarrollo del proceso, la descripción del sistema de negociación y el papel del supervisor europeo de los registros nacionales (el Community Independent Transaction Log, CITL, en sus siglas en inglés) la obligación de la vinculación al registro de Naciones Unidas (el International Transaction Log, ITL, en sus siglas en inglés) para participar en el mercado internacional de permisos de emisión, el seguimiento del cumplimiento de los objetivos y la verificación de las emisiones reales, así como la discusión sobre la continuación del EU ETS después de la fase de cumplimiento del Protocolo de Kyoto (es decir, a partir de 2012).

Una vez entendido el funcionamiento del esquema de comercialización de permisos de emisión en Europa, se procede a la presentación de las diferentes formas en las que se puede llevar a cabo la negociación de dichos permisos. Se estudia el mercado parte a parte así como los mercados organizados, tanto al contado como a futuro. Para ello se describen tanto las normas de negociación en cada uno de los mercados europeos en los que es posible negociar cada tipo de contrato como la evolución de los precios en los diferentes mercados y las relaciones de correlación entre ellos. También se proporciona información sobre los volúmenes negociados tanto por mercados como por fases del EU ETS. Del mismo modo se estudian los contratos a nivel internacional.

A partir de este análisis, se deduce que los precios siguen una evolución muy parecida independientemente de qué mercado europeo se considere. Además, los niveles de precios son también muy semejantes. Estas características se constatan tanto si se considera la Fase I como la Fase II. En lo que se refiere a los volúmenes, el mercado organizado que más volumen registra durante la Fase I del EU ETS es el mercado de futuros. La mayor parte de esta negociación se hace en el mercado inglés, el European Climate Exchange. Sin embargo, la mayor parte de la negociación a contado se realiza a través del mercado francés Bluenext.

No obstante, puesto que el EU ETS no es el único mercado que se deriva del mecanismo de flexibilidad del protocolo de Kyoto, también es interesante considerar cómo se lleva a cabo la vinculación del mercado europeo con (i) los mercados internacionales de permisos de emisión de gases de efecto invernadero derivados del protocolo de Kyoto y por lo tanto bajo la supervisión de Naciones Unidas y (ii) con los otros mecanismos de flexibilidad de dicho protocolo. Estos otros mecanismos consisten básicamente en la realización de proyectos de reducción de emisiones, promovidos por los países que han ratificado el protocolo de Kyoto, en otro país. El país patrocinador recibe un número de permisos de emisión equivalente a las emisiones evitadas en el país en el que se desarrolla el proyecto.

En el caso de que el proyecto se realice en un país que haya a su vez ratificado el protocolo de Kyoto, el mecanismo de flexibilidad recibe el nombre de Mecanismo de Aplicación Conjunta (JI, en sus siglas en inglés) y en el caso de que el proyecto se desarrolle en un país no industrializado, el mecanismo de flexibilidad recibe el nombre de Mecanismo de Desarrollo Limpio (CDM, en sus siglas en inglés).

Los permisos de emisión de gases de efecto invernadero generados por estos proyectos reciben el nombre de Unidades de Reducción de Emisiones (ERUs, en sus siglas en inglés) en el caso del mecanismo de Aplicación Conjunta y Certificados de Reducción de Emisiones (y CERs, en sus siglas en inglés) en el caso del Mecanismo de Desarrollo Limpio. Estos permisos, al igual que los EUAs, pueden negociarse en los mercados internacionales y pueden utilizarse para el cumplimiento de los objetivos de reducción de emisiones.

Junto con el registro internacional, el International Transaction Log, que permite la negociación de permisos a nivel mundial, estos mecanismos de proyectos son muy importantes para la mitigación de las emisiones de gases de efecto invernadero a nivel global. Además, gracias a estos mecanismos, los países no industrializados desempeñan un papel importantísimo en dicha reducción de emisiones, al mismo tiempo que pueden beneficiarse de cierta transmisión de tecnología.

En este capítulo también se comenta que en los mercados de carbono, hay una gran variedad de participantes. En primer lugar podemos considerar los agentes industriales directamente afectados por la reducción de emisiones en sus procesos de producción, pero también existen intermediarios e instituciones financieras, que juegan un papel fundamental en el desarrollo de este tipo de mercados. Además, hay que tener en cuenta la importancia en el mercado de los agentes que participan en la elaboración de proyectos ya sea de aplicación conjunta o utilizando el mecanismo de desarrollo limpio. Este tipo de agentes aumentan la oferta de permisos disponible cuando introducen los permisos obtenidos con los proyectos en el mercado internacional.

Como conclusión general de este capítulo me gustaría subrayar algunos aspectos: (i) el EU ETS ha conseguido imponer un precio a las emisiones de CO_2 y por lo tanto ha alcanzado uno de sus objetivos más importantes, (ii) el volumen de negociación de todo tipo de contratos, tanto al contado, como a futuro está aumentando de forma muy pronunciada, (iii) los contratos de opciones han empezado a desarrollarse recientemente en los mercados organizados (nótese que los agentes del mercado consideran que la negociación de este tipo de contratos en mercados organizados es signo de madurez del mercado de futuros y además contribuirá a crear mayor liquidez en dicho mercado), (iv) el mercado secundario de CERs es el segmento que más se está desarrollando y según las estimaciones, contribuirá a que la oferta y la demanda en los mercados de carbono llegue al equilibrio.

CAPÍTULO 2: Precios de CO_2, Energía y Clima

El **segundo capítulo** se titula "***Precios de CO_2, Energía y Clima***". Como hemos visto, uno de los principales objetivos del EU ETS y uno de sus mayores éxitos, es el establecimiento de un precio para el CO_2. El objetivo de este capítulo es analizar el efecto de ciertas variables climáticas y no climáticas, sobre dicho precio y más concretamente sobre los rendimientos a plazo diarios de CO_2 durante 2005 (el primer año de la Fase I del EU ETS). Para ello analizamos varios modelos que corroboran la influencia de variables energéticas y climáticas en los rendimientos del CO_2. Como se explica a continuación, nos basamos en hipótesis de modelos teóricos y en sugerencias hechas por los agentes de mercado para guiarnos en nuestro análisis y en la elección de dichas variables.

Una de las mayores dificultades para la realización de este capítulo ha sido la ausencia de estudios empíricos en la literatura científica que analizaran esta problemática. Sin embargo, en el momento de la elaboración del capítulo, existían explicaciones teóricas para los determinantes de los precios del carbono así como artículos basados en simulaciones que introducen el impacto en la economía de tener un precio de CO_2. Asimismo, desde la creación del EU ETS, han aparecido publicaciones realizadas por agentes del mercado sobre la evolución de los precios de CO_2 en Europa y existía una idea de qué variables podían considerarse determinantes de dichos precios.

La mayor parte de los modelos teóricos que tratan el tema de la determinación de los precios de CO_2 sugieren que tanto variables energéticas como factores climáticos pueden influenciar los precios de los permisos de emisión. Estos factores, en general coinciden con las percepciones de los agentes de mercado.

Las variables energéticas que hemos utilizado en nuestros modelos son las variables energéticas más relevantes a nivel europeo: Brent y gas natural, negociados en el International Petroleum Exchange (IPE) así como precios de carbón publicados por el broker Traditional Financial Services (TFS), concretamente TFS API 2 ARA. En todos los casos hemos cogido las series de precios de futuro que mejor corresponden con la serie de precios de EUAs utilizada (*Carbon Index* publicado por el mercado alemán, el EEX). Además hemos querido considerar el impacto del cambio relativo entre los precios de gas y carbón para lo que hemos creado una variable adicional.

En lo que se refiere a las variables climáticas, hemos querido tener en cuenta el impacto del clima en Alemania sobre los precios de CO_2 (puesto que los precios de CO_2 utilizados representan operaciones cerradas entre los participantes del EEX que durante el periodo muestral eran principalmente alemanes) así como el clima agregado a nivel europeo. Para ello hemos construido índices de temperatura y pluviosidad que representan ambos climas y hemos analizado el efecto del clima extremo y persistente para cada caso por separado.

Los resultados muestran que las variables que tienen un impacto mayor en la determinación de los precios de CO_2 son el Brent y el gas natural. Además, se observa que los días extremadamente cálidos o fríos en Alemania tienen un impacto positivo en los precios del CO_2. Sin embargo, no se observa influencia estadísticamente significativa sobre el precio del CO_2 de la fuente energética más intensiva en emisiones (el carbón) ni tampoco de la variable que recoge la posibilidad de cambiar de fuente de producción de energía en función de los precios relativos entre el gas natural y el carbón. Por otra parte, todas las variables que son estadísticamente significativas y que por lo tanto tienen un impacto sobre los precios del CO_2, lo tienen con el signo esperado y esto muestra cierta racionalidad del mercado europeo de permisos de emisión en su primer año de funcionamiento. Es decir, el precio a plazo del CO_2 refleja condiciones subyacentes a nivel microeconómico y por consiguiente, el mercado de CO_2 no es tan irracional, durante este periodo, como algunos observadores han sugerido.

Además de determinar las variables que afectan en mayor medida a los precios de CO_2 durante el primer año de negociación, este estudio nos permite analizar también la relación entre variables energéticas y CO_2, así como esclarecer la forma funcional entre las variables climáticas y el CO_2.

En este capítulo no queremos explicar el nivel medio de los precios de CO_2 durante el periodo estudiado con respecto a las expectativas, sino que queremos centrar nuestro interés en los rendimientos diarios durante el 2005. El objetivo es intentar examinar la posible racionalidad subyacente de la forma en la que se establecen los precios de CO_2 durante el primer año de EU ETS.

CAPÍTULO 3: El impacto de los Planes Nacionales de Asignación sobre los precios de CO_2

El **capítulo 3** se titula "***El impacto de los Planes Nacionales de Asignación sobre los precios de CO_2***". En este capítulo se estudia la eficiencia del mercado en sus comienzos. La estructura de los mercados de emisiones y la legislación Europea que organiza las obligaciones de los Estados Miembros, hace que la publicación de información relativa a diversos aspectos que pueden tener una influencia sobre los mercados de CO_2, se produzca de forma esporádica. Entre estos aspectos se encuentran las noticias (i) relacionadas con los NAPs, documentos elaborados por los estados miembros en los que se fija tanto la cantidad total de permisos de emisión disponible como la asignación a cada instalación cubierta por el EU ETS y (ii) los anuncios de las emisiones reales verificadas. Concretamente, en este capítulo se analiza el impacto de los anuncios oficiales hechos por la comisión europea que se refieren a anuncios sobre los NAPs y a la verificación de emisiones reales sobre los precios y la volatilidad de los EUAs.

La forma en la que llega esta información a los mercados de CO_2 europeos tiene ciertas características que la hacen atractiva tanto para su estudio a nivel académico como para los participantes del mercado: es esporádica y numerosa. Para realizar este estudio hemos considerado el periodo desde octubre 2004 hasta mayo 2007, durante el cual, más de 70 anuncios oficiales fueron registrados.

En la literatura relativa a los mercados de futuros, hay numerosos artículos que utilizan la metodología del estudio de eventos para determinar como y cuando la información llega al mercado, en una gran variedad de contextos. Según McKenzie et al. (2004), en la literatura se utilizan principalmente dos tipos de enfoques. El primero consiste en estimar los rendimientos anormales como coeficientes de una regresión con variables *dummy* que corresponden a los días en los que se produce el evento (veáse Christie-David and Chaudhry (2000), Lusk and Schroeder (2002) and Simpson and Ramchander (2004), entre otros). El segundo enfoque es el que utiliza el modelo *Constant Mean Return Model*, que obtiene los rendimientos anormales a partir de un periodo de referencia (véase Mann and Dowen (1997) and Tse and Hackard (2006), entre otros). En este capítulo utilizamos los dos enfoques de la metodología de estudio de eventos utilizando rendimientos diarios de los precios a futuro del CO_2.

Sin embargo, las particularidades de nuestra serie de datos hacen que sea necesario adaptar la metodología del estudio de eventos dada la elevada cantidad de anuncios cercanos en el tiempo que afectan a una sola serie de precios. Con la intención de minimizar las grandes sorpresas durante el periodo de predicción cuando aplicamos el *Constant Mean Return Model*, proponemos utilizar en su lugar, el modelo de Media Truncada, que es una modificación del modelo *Constant Mean Adjusted Return Model*, en el que los rendimientos anormales en el periodo de estimación se obtienen utilizando una media truncada.

Es decir, en este capítulo hemos adaptado la metodología tradicional del estudio de eventos utilizada en otros mercados financieros para, por un lado, hacer frente a ciertas especificidades del mercado de CO_2 y por el otro, minimizar grandes sorpresas durante el periodo de predicción.

Los resultados obtenidos muestran que, por lo que respecta a los efectos de los anuncios relativos a los NAPs sobre los rendimientos del CO_2, tanto los anuncios de la Fase I como de la Fase II tienen una influencia sobre los rendimientos del CO_2 el día del anuncio y en unos pocos casos también durante los días siguientes. Sorprendentemente, también hemos detectado rendimientos significativos en días previos al anuncio.

Con respecto al impacto de este tipo de anuncios sobre la volatilidad, no hemos encontrado ningún efecto significativo antes ni después del anuncio oficial.

Las dos constataciones, la presencia de rendimientos anormales estadísticamente significativos hasta tres días antes del anuncio relacionado con los NAPs y la ausencia de efectos de volatilidad cuando la información es revelada, indican que ha habido filtración de información antes del anuncio.

Estos resultados apoyan la petición hecha por la European Federation of Energy Traders (EFET, 2006) a la Comisión Europea como consecuencia de la publicación de las emisiones verificadas del año 2005 que tuvieron lugar en mayo de 2006. Concretamente

EFET pidió que la información importante que pueda tener un efecto sobre el precio del CO_2 debiera ser *exacta, final, y que se publique de tal forma que sea accesible a todos los participantes del mercado al mismo tiempo*.

CAPÍTULO 4: Precios de CO_2 y Gestión de Carteras

Por último, el **cuarto capítulo** lleva por título "***Precios de CO_2 y Gestión de Carteras***". Como hemos visto, el EU ETS se organiza en dos fases. La Fase I empezó en enero 2005 y la Fase II en enero 2008. Puesto que la transferencia de permisos entre fases no está permitida, los activos negociados en cada una de las fases deben considerarse como activos diferentes. Es decir, los precios de futuro con vencimiento diciembre 2007, no tienen porqué coincidir, y de hecho a partir de mayo 2006 no coinciden, con los precios de futuro con vencimiento 2008. Por lo tanto, durante la Fase I del EU ETS se negociaron simultáneamente dos tipos de activos que representaban el permiso de emitir una tonelada de CO_2 en la Unión Europea. La diferencia entre los dos activos es el periodo de tiempo en el que la emisión de dicha tonelada de CO_2 puede tener lugar. Nótese que a partir de abril de 2008 la negociación los EUA Fase I dejó de realizarse y por lo tanto el interés de estudiarlo es simplemente observar lo qué pasó en la fase piloto del EU ETS.

Para el propósito de este capítulo también es importante señalar que, como se muestra en el capítulo uno, las instalaciones cubiertas por la directiva 2003/87/CE (los grandes emisores de CO_2) no son las únicas participantes que pueden formar parte del EU ETS. Cualquier persona natural o jurídica está autorizada a abrir una cuenta y a participar en la negociación de emisiones. Por lo tanto, es interesante estudiar si el lanzamiento del EU ETS ha creado nuevas oportunidades de inversión también para estos participantes que no tienen obligación de reducción de emisiones y que por lo tanto no utilizan el EU ETS para cumplir con sus objetivos.

Desde que Markowitz publicara su artículo "Portfolio Selection" en el *Journal of Finance*, en 1952, muchos autores se han interesado por el estudio de los beneficios de la diversificación en una amplia variedad de contextos. Grubel (1968) and Eun and Resnick (1988), entre otros, tratan de mostrar si una cartera está mejor diversificada si se incluyen activos de otros países (diversificación internacional). En otros casos, los autores estudian las oportunidades que brinda la diversificación cuando se introducen nuevos activos. Por ejemplo, Ibbotson and Siegel (1984), Kuhle (1987) and Chandrashekaran (1999), entre otros, comparan los Real Estate Investment Trusts (fondos de inversión inmobiliaria) con otras oportunidades de inversión para estudiar la capacidad de estos activos de mejorar la diversificación de la cartera (diversificación por activos). Otro ejemplo es el caso de autores como Jensen et al. (2002), Gorton and Rouwenhorst (2004), and Erb and Harvey (2006) que analizan el impacto de introducir índices de materias primas como el Goldman Sachs Commodity Index (GSCI), en la gestión de cartera.

El estudio del efecto que sobre la diversificación de la cartera pueda tener la introducción en la misma de EUAs es el principal objetivo de este capítulo. Las razones por las que consideramos que este análisis es particularmente oportuno son principalmente dos: (i) el interés de los inversores en los mercados de carbono está aumentando constantemente y (ii) la Fase I del EU ETS acaba de terminar por lo que se puede hacer un análisis completo de lo que ocurrió en la fase piloto. Concretamente, en este capítulo intentamos describir los efectos de introducir este nuevo activo en una cartera ya diversificada durante la Fase I del EU ETS. Además, también analizamos bajo que condiciones la existencia de EUAs incrementa las oportunidades de inversión de un inversor europeo durante la Fase II del EU ETS. Los resultados obtenidos son interesantes tanto desde un punto de vista académico como para los participantes del mercado.

Para realizar este estudio, empezamos por interesarnos por las características de los EUAs Fase I y Fase II como única inversión. Hemos podido confirmar que ambos activos presentan rendimientos no demasiado elevados y desviaciones estándar bastante elevadas. Esto hace que los dos activos presenten un ratio de Sharpe bajo (especialmente en el caso de los EUAs de la Fase I). Por lo tanto, podemos deducir que este tipo de activos, como única inversión, no son demasiado convenientes. Sin embargo, si consideramos que el rendimiento del EUA Fase I ha sido negativo durante dicha fase, podemos considerar la posibilidad de vender dicho activo.

A continuación hemos estudiado el efecto de introducir estos dos activos, separadamente, en una cartera diversificada, compuesta por activos tradicionales y variables energéticas. Entre los activos tradicionales figuran la renta fija y la renta variable. Los activos que hemos considerado para la renta fija son los contratos más negociados en Europa: Euro Schatz Futures, Euro Bolb Futures and Euro Bund Futures para los vencimientos de 2, 5 y 10 años, aproximadamente, respectivamente. Con respecto a la renta variable hemos considerado la serie de precios de futuro del Dow Jones Euro Stoxx 50. Las variables energéticas consideradas son también las más representativas en Europa; concretamente hemos utilizado precios de futuro de Brent y de gas natural negociados en el International Petroleum Exchange. La variable que hemos considerado libre de riesgo ha sido el EURIBOR a un mes.

A partir de estos activos, hemos considerado seis combinaciones diferentes de activos para elaborar seis carteras a partir de las cuales hemos introducido los EUAs Fase I y Fase II y hemos estudiado el impacto de introducir estos dos activos en los rendimientos y la volatilidad de la cartera. Las ponderaciones de los diferentes activos que hemos utilizado para elaborar las diferentes carteras son las siguientes:

- Cartera I: 50% acciones y 50% renta fija,
- Cartera II: 80% Cartera I y 20% variables energéticas,
- Cartera III: 80% Cartera I y 20% CO_2 Fase I,
- Cartera IV: 80% Cartera I y 20%CO_2 Fase II,
- Cartera V: 80% Cartera I, 10% variables energéticas y 10% CO_2 Fase I,
- Cartera VI: 80% Cartera I, 10% variables energéticas y 10% CO_2 Fase II.

Así pues, utilizando la metodología de Markowitz (1952), hemos obtenido las fronteras eficientes para cada una de estas carteras. El análisis lo hemos realizado utilizando rendimientos históricos y rendimientos ajustados por riesgo para la obtención de los rendimientos esperados. En ambos casos los resultados son muy parecidos.

En primer lugar encontramos que introducir permisos de emisión de CO_2 para la Fase I o para la Fase II, puede aumentar el conjunto de oportunidades de inversión de un inversor que inicialmente invierte en activos tradicionales (acciones y renta fija). Sin embargo, las oportunidades que proporcionó la introducción del CO_2 Fase I en la cartera fueron más importantes que las que presentó la inversión de CO_2 Fase II durante el periodo muestral.

Si consideramos un inversor que ya tiene en su cartera cierta representación de variables energéticas, únicamente la introducción de CO_2 Fase I pudo incrementar su conjunto de oportunidades de inversión. Sin embargo, independientemente de qué método utilicemos para obtener los rendimientos esperados obtenemos que la cartera que incluye variables energéticas permite obtener mejores combinaciones rendimiento-riesgo que la cartera que incluye CO_2 Fase II.

Finalmente, en este capítulo también se analiza cómo se introducen los EUAs en la cartera óptima para la cual hemos fijado un rendimiento objetivo de 3%, 5% o 10%. En este sentido obtenemos que las ponderaciones de los EUAs en la cartera óptima no son demasiado importantes y que en la mayoría de los casos, es necesario permitir las ventas al descubierto para que los EUAs sean introducidos en la cartera óptima. Este es sobretodo el caso cuando consideramos los EUAs Fase I, que acabaron con precios muy cercanos a cero durante 2007.

Comentarios finales

En esta tesis hemos intentado responder a algunas de las preguntas que surgen con la creación de los mercados de CO_2 y que se refieren básicamente al funcionamiento de dichos mercados, a los determinantes de los precios del CO_2, al análisis de la eficiencia de este nuevo mercado y a las implicaciones de la existencia de dos nuevos activos en la gestión de cartera. Hemos intentado responder de forma rigurosa a estas preguntas que interesan tanto desde el punto de vista académico como a los participantes del mercado y a los reguladores.

Dada la falta de datos cuando empezamos esta tesis (un año de datos para el segundo capítulo, dos años para el tercero y tres para el cuarto), hemos utilizado a lo largo de la tesis técnicas no-paramétricas que nos han permitido evitar hacer supuestos sobre la distribución de los rendimientos del CO_2. Además, en el capítulo 3, tuvimos que adaptar la metodología a nuestro caso particular y en el capítulo 4 no tuvimos más remedio que considerar la gestión de cartera utilizando EUAs, considerando un horizonte de inversión de corto plazo. Por lo tanto, la expansión natural de esta tesis es considerar periodos muestrales más largos y ampliar el número de datos históricos. Esto solo será posible a medida que el EU ETS se desarrolle así como el resto de mercados internacionales de CO_2. Por otra parte, el capítulo 1 deberá actualizarse constantemente, sobretodo teniendo en cuenta que la preparación de la Fase III del EU ETS y las negociaciones internacionales sobre el post-Kyoto se están desarrollando en estos momentos.

Si consideramos series más largas, en el capítulo 2 podremos incluir otro tipo de variables (relacionadas con la economía y con el clima) como determinantes de los precios de CO_2. Entre las variables económicas podemos considerar que la evolución del PIB puede tener un impacto sobre los precios del CO_2 (un incremento en la producción debería provocar un incremento en la demanda energética y por lo tanto un incremento de los precios de CO_2). Además podemos considerar el desarrollo de actividades que pretenden mantener o aumentar la producción reduciendo las emisiones y que serán fundamentales a la hora de establecer los precios de equilibrio en la Fase II del EU ETS.

Por lo que se refiere a las variables climáticas que puedan tener un efecto a largo plazo sobre los precios del CO_2 podemos pensar en elementos como el nivel de agua en los embalses (una reducción significativa en el nivel de los embalses puede producir una reducción de la producción de electricidad hidráulica y puede ser relevante para determinar los precios de CO_2 a largo plazo). Nótese que en ambos casos estamos hablando de variables que presentan cambios sustanciales en el largo plazo y por lo tanto, no pueden utilizarse para analizar los determinantes de los precios del CO_2 en el corto plazo pero están perfectamente justificadas para analizar los determinantes a largo plazo del CO_2.

Nótese además que hemos analizado los determinantes de los precios de CO_2 desde el punto de vista de la demanda. La razón principal es que la oferta en el EU ETS es una decisión política y por lo tanto, las políticas públicas relacionadas con el cambio climático son también uno de los principales factores que inciden en el precio del CO_2.

En lo que se refiere al capítulo 3, sería interesante considerar la existencia de anuncios no oficiales, tales como los publicados por Point Carbon, que pueden tener un impacto en los precios de CO_2 pues son seguidos por un gran número de participantes del mercado. La razón principal por la que no hemos considerado en este análisis este tipo de anuncios es porque queríamos analizar el impacto de anuncios *oficiales* sobre los precios de CO_2.

Con respecto al capítulo 4, disponer de series de precios más largas nos permitiría cambiar el horizonte temporal del inversor y considerar los intereses de un inversor a largo plazo. Preguntas como si es financieramente interesante para un inversor a largo plazo invertir en activos con tan elevada volatilidad podrían responderse si dispusiéramos de series más largas. Además, también sería posible analizar las propiedades de cobertura de estos activos para hacer frente a la inflación o a otras variables macroeconómicas que cambian con periodos de tiempo más largos. Otra posibilidad sería introducir los rendimientos de CO_2 como variable explicativa en los modelos de valoración para empresas que tienen objetivos vinculantes de reducción de emisiones.

Como conclusión general quisiéramos subrayar que el EU ETS ha conseguido establecer un precio para las emisiones de CO_2 que, como hemos visto, es fundamental para luchar contra el cambio climático y es uno de los principales objetivos del lanzamiento de este mercado. Es verdad que durante la Fase I no se creó la escasez suficiente en el mercado y por lo tanto el precio al final de dicha fase fue muy bajo. Sin embargo, aunque un precio bajo no consigue incentivar una reducción de emisiones suficiente, no hay que olvidar que, como destaca la Comisión Europea, la Fase I ha servido para crear la experiencia necesaria para facilitar que todos los participantes del mercado consigan sus objetivos en la fase siguiente. Desde este punto de vista, la fase I debe ser considerada como una fase piloto.

RESUMÉ

Ces derniers temps, l'importance que le changement climatique a sur notre société ne cesse d'augmenter. Dans son dernier rapport publié en 2007, intitulé «Changements Climatiques 2007: Rapport de Synthèse», le Groupe Intergouvernemental d'Experts sur l'évolution du Climat (IPCC dans son acronyme en anglais) prévient qu'il n'y a pas de doute sur les causes anthropiques du changement climatique. Dans ce même rapport, le GIEC exhorte les gouvernements à trouver une solution à l'un des problèmes les plus importants du vingt et unième siècle.

Une des réponses provoquée aussi bien par la nécessité d'atténuation des changements climatiques que par la celle de s'adapter à leur conséquences les plus immédiates, a été l'émergence d'un nouveau concept dans les sociétés modernes: la Finance Carbone (Carbon Finance, en anglais). Selon Labatt et White (2006) la Finance Carbone examine les solutions financières pour vivre dans un monde soumis à la limitation des émissions de dioxyde de carbone et d'autres gaz à effet de serre, dans lequel ces gaz ont un prix. Les marchés de carbone sont une partie importante de la Finance Carbone, mais pas la seule. Le mise au point de projets pour réduire les émissions de gaz à effet de serre (de nouvelles opportunités pour les stratégies de gestion alternative) ainsi que certaines politiques du gouvernement sont, entre d'autres, des piliers fondamentaux de la Finance Carbone.

Le rapport Stern (2006) souligne également la nécessité d'établir un prix pour les émissions de gaz à effet de serre. Selon ce rapport, pour être en mesure d'articuler un

système efficace, efficient et équitable face au changement climatique, il est nécessaire de disposer de signaux de prix et donc de marchés du carbone.

L'émergence et la formation du prix du carbone a été possible, entre autres raisons, grâce à l'une des plus importantes politiques internationales pour réduire les émissions de gaz à effet de serre au niveau mondial, le Protocole de Kyoto. Ce protocole est entré en vigueur le 16 Février 2005. Il s'agit d'un instrument juridiquement contraignant de réduction des émissions qui établit, pour les pays industrialisés qui l'ont ratifié, des objectifs quantifiés. Ces réductions doivent avoir lieu au cours de la période 2008-2012. Toutefois, il existe trois mécanismes de flexibilité qui permettent de faciliter l'atteinte de leurs objectifs par les pays.

Parmi ces mécanismes, nous devons considérer l'échange de quotas d'émission (article 17 du Protocole de Kyoto), qui a joué un rôle crucial dans le lancement du marché européen des quotas d'émissions (EU ETS, dans son acronyme en anglais). Selon Lowrey (2006), malgré le fait que les principaux objectifs de l'EU ETS sont (i) la réduction des émissions de CO_2, (ii) la promotion des technologies propres, (iii) l'efficacité énergétique, l'objectif qui parait le plus important est la création d'un prix de marché pour les quotas d'émissions. La mise en place d'un tel prix européen signifie que les installations plus polluantes en termes de CO_2 sont conscientes des conséquences financières de leurs activités polluantes.

L'EU ETS, est le marché financier pour l'environnement le plus important au monde. Par rapport au marché pour le SO_2 américain, l'EU ETS comprend un plus grand nombre d'installations, et le montant des émissions couvertes par le marché, ainsi que la valeur des actifs créés et distribués sont plus élevés. Dans le cadre de ce régime, qui a été lancé le premier Janvier 2005, les installations européennes qui produisent une quantité importante d'émissions de CO_2 reçoivent de leurs gouvernements, par le biais des Plans Nationaux d'Allocation de Quotas (NAPs dans son acronyme en anglais), des permis d'émission pour chaque phase de l'EU ETS (Phase I et Phase II). La Phase I, considérée comme une phase pilote, comprend les années 2005-2007, tandis que la Phase II coïncide avec la période de conformité avec le protocole de Kyoto et, donc, comprend les années 2008-2012. Les quotas d'émission sont appelés par leur acronyme en anglais des EUAs (European Union Allowances) et permettent l'émission d'une tonne de CO_2 dans un pays de l'Union européenne. Grace à l'EU ETS, il est possible, à condition que les installations répondent à leurs objectifs de réduction des émissions à temps voulu, de marchander les EUAs dans plusieurs marchés européens, aussi bien au comptant, qu'en utilisant les contrats à terme et les contrats d'options.

L'étude des marchés du carbone fait partie des préoccupations du domaine de la finance. C'est pourquoi, depuis le lancement de l'EU ETS, le nombre d'articles académiques qui se sont intéressés à ces types de marchés ont connu une augmentation considérable. Cependant, au début de cette thèse (Septembre 2005), il n'y avait pas d'articles de recherche empirique qui examinaient le comportement des marchés financiers de CO_2. Par conséquent, l'un de ses principaux objectifs est d'enrichir la littérature dans ce domaine.

Cette thèse est divisée en quatre chapitres. Chacun examine le marché européen des émissions de CO_2 sous un angle différent.

CHAPITRE 1: La négociation de CO_2

Plus précisément, le premier chapitre est intitulé «La négociation de CO2 » et son principal objectif est de décrire l'état de la situation des marchés de quotas. Depuis la ratification du protocole de Kyoto par un grand nombre de pays, la négociation de quotas d'émission s'est développée de façon continue et, par conséquent, il existe un intérêt croissant dans l'étude de ce phénomène.

Toutefois, nous avons commencé ce chapitre par les origines de la négociation des quotas d'émission au niveau européen. Tout d'abord, nous présentons le protocole de Kyoto et le marché des droits d'émission comme l'un des trois mécanismes de flexibilité. Ce chapitre explique quelles sont les différentes possibilités à la disposition des pays qui ont signé le protocole de Kyoto, pour atteindre ses objectifs particuliers. Il fournit également une description détaillée des objectifs par pays et de leur état d'accomplissement, en accordant une attention particulière aux pays européens.

D'autre part, nous prenons aussi compte du fait qu'avant le lancement de l'EU ETS, il ya eu plusieurs expériences de négociation de quotas d'émissions dans plusieurs parties du monde et nous fournissons quelques détails. Toutefois, l'EU ETS est, à ce jour, et comme indiqué auparavant, le marché le plus important au niveau mondial de négociation de quotas d'émission de gaz à effet de serre. Par conséquent, il est important de comprendre son fonctionnement, son articulation et son organisation.

Ainsi, une description détaillée de l'EU ETS est prévue dans le présent chapitre. Dans cette description nous considérons tous les aspects couverts par la directive européenne réglementant ce marché (2003/97/CE) et essayons d'en donner une vision aussi large que possible. Les sujets couverts comprennent les secteurs européens soumis à la directive, les Plans Nationaux d'Allocation et son importance dans le processus de développement du marché, la description du système de négociation et le rôle du superviseur européen de registres nationaux (Community Independent Transaction Log, CITL dans son acronyme en anglais), l'obligation de se connecter au registre des Nations Unies (International Transaction Log, ITL, dans son acronyme en anglais) pour pouvoir participer au marché international des quotas, la nécessité d'assurer la conformité des objectifs et la vérification des émissions réelles, ainsi que la discussion sur la poursuite de l'EU ETS après la période d'engagement du Protocole de Kyoto (c'est-à-dire, à partir de 2012).

Une fois expliqué le fonctionnement du marché des quotas en Europe, nous présentons les différentes formes dont les quotas d'émissions peuvent être négociées. Nous considérons le marché de gré à gré ainsi que les marchés organisés, à la fois les contrats de futures et d'options. Nous décrivons les règles de négociation dans chacune des places de marchés sur lesquelles il est possible de négocier chaque type de contrat et nous analysons l'évolution des prix dans les différents marchés ainsi que les relations de corrélation entre eux. Des informations concernant les volumes négociés dans les différents marchés ainsi que sur les deux Phases de l'EU ETS sont fournies. Les contrats au niveau international sont également étudiés.

De cette analyse, nous pouvons dire que l'évolution des prix est toujours très semblable, quel que soit le marché européen considéré. En outre, les niveaux de prix sont également très similaires. Ces caractéristiques sont identifiées, si l'on considère la Phase I et Phase II. En termes de volumes, le marché organisé qui présente un plus gros volume est le marché à terme. La plupart de cette négociation se fait dans le marché anglais, l'European Climate Exchange. Toutefois, la plupart de la négociation au comptant s'effectue dans le marché français Bluenext.

Néanmoins, puisque l'EU ETS n'est pas le seul marché qui s'est dérivé du mécanisme de flexibilité du protocole de Kyoto, il est également intéressant d'examiner comment s'effectue la liaison du marché européen avec (i) les marchés internationaux de quotas d'émissions de gaz à effet de serre du protocole de Kyoto et, par conséquent, sous la supervision de l'ONU et (ii) avec les autres mécanismes de flexibilité du protocole de Kyoto. Ces mécanismes sont essentiellement l'élaboration de projets de réduction des émissions promus par les pays qui ont ratifié le protocole de Kyoto, dans un autre pays. Le pays développeur du projet reçoit un nombre de quotas équivalent aux émissions évitées dans le pays dans lequel le projet a été développé.

Dans le cas où le projet se déroule dans un pays qui a à son tour ratifié le protocole de Kyoto le mécanisme de flexibilité s'appelle Mécanisme de Mise en Œuvre Conjointe (JI, dans son acronyme en anglais). En revanche, dans le cas où le projet est développé dans un pays non industrialisé, le mécanisme de flexibilité s'appelle Mécanisme de Développement Propre (CDM, dans son acronyme en anglais). Les quotas de gaz à effet de serre générés par ces projets sont appelés unités de réduction des émissions (ERUs, dans son acronyme en anglais) dans le cas du Mécanisme de Mise en Œuvre Conjointe et réductions certifiées des émissions (CERs, dans son acronyme en anglais) dans le cas du Mécanisme de Développement Propre. Comme dans le cas des EUAs, ces permis peuvent être négociés dans les marchés internationaux ou peuvent être utilisés pour atteindre les objectifs de réduction.

Par le biais de ces mécanismes, les pays non industrialisés jouent un rôle très important dans la réduction des émissions globales de CO_2 en même tems qu'ils bénéficient d'un certain transfert technologie.

Ce chapitre indique également qu'il existe une grande variété de participants dans le marché du carbone. Tout d'abord, nous considérons les acteurs industriels directement concernés par la réduction des émissions de leur processus de production, mais il ya aussi les courtiers et les institutions financières, qui jouent un rôle clé dans le développement de ces marchés. En outre, nous devons tenir compte de l'importance dans ce marché de ceux qui sont impliqués dans le développement de projets. Ce type d'acteurs augmente l'offre de quotas disponibles dans le marché lorsqu'ils introduisent les quotas de réductions issus des projets.

En conclusion de ce chapitre, je tiens à souligner certains points: (i) l'EU ETS a réussit à imposer un prix aux émissions de CO_2 et a donc atteint un de ses principaux objectifs, (ii) le volume négocié de tous les types de contrats, à la fois au comptant que à terme sont en forte augmentation, (iii) les contrats d'options ont commencé à se développer récemment dans des marchés organisés (à noter que les acteurs du marché estiment que la négociation d'un tel contrat dans des marchés organisés est un signe de maturité du marché à terme et aider également à créer une plus grande liquidité dans ce marché), (iv) le marché secondaire des CERs est le segment qui se développe le plus ; il est estimé qu'il va beaucoup contribuer à l'équilibre entre l'offre et la demande dans les marchés du carbone.

CHAPITRE 2: Prix du CO_2, Énergie et Climat

Le deuxième chapitre est intitulé « Prix du CO_2, Énergie et Climat ». Comme nous l'avons vu, l'un des principaux objectifs de l’EU ETS et l'un de ses plus grands succès, est l'établissement d'un prix pour le CO_2. L’objectif de ce chapitre est d'étudier l'impact de certaines variables climatiques et non climatiques sur ce prix, et plus particulièrement sur les variations journalières de prix du contrat à terme de CO_2 en 2005 (la première année de la phase I de l’EU ETS). Pour ce faire, nous avons analysé plusieurs modèles qui indiquent qu’il y a une certaine l'influence des variables énergétiques et des variables climatiques dans les variations de prix du CO_2. Comme expliqué ci-dessous, nous nous sommes fondés sur les hypothèses des modèles théoriques et les suggestions formulées par les acteurs du marché pour nous guider dans notre étude.

L'une des principales difficultés dans l’élaboration de ce chapitre a été l'absence d'études empiriques dans la littérature scientifique qui traite cette problématique. Toutefois, au moment de la préparation de ce chapitre, il y a eu des explications théoriques concernant la détermination du prix du carbone ainsi que des articles basés sur des simulations qui introduisent l'impact sur l'économie d'avoir un prix du CO_2. Aussi, depuis la création de l’EU ETS, des publications élaborées par des acteurs du marché sur l'évolution des prix des émissions de CO_2 en Europe sont apparues et il y avait une idée de ce qui pourrait être considéré comme des variables qui déterminent ces prix.

La plupart des modèles théoriques qui traitent de la question de la fixation des prix des quotas suggèrent que les variables énergétiques ainsi que certains facteurs climatiques peuvent influer sur le prix des quotas d'émissions. Ces facteurs, en général d'accord avec les perceptions des acteurs du marché.

Les variables énergétiques que nous avons utilisé dans nos modèles, sont les variables les plus importantes au niveau européen: le Brent et le gaz naturel, tous les deux négociés sur l'International Petroleum Exchange (IPE) ainsi que les prix du charbon publiée par le courtier traditionnel Financial Services (TFS), en particulier TFS API 2 ARA. Dans tous les cas, nous avons utilisé les séries de prix à terme qui était le plus compatible avec la série de prix d'EUA utilisée (le *Carbon Index* publié par le marché allemand, le EEX). En outre, nous avons voulu examiner l'impact de la variation du prix du gaz par rapport à celui du charbon et pour ceci nous avons créé une variable supplémentaire.

En termes de variables climatiques, nous avons voulu prendre en compte l'impact des conditions météorologiques en Allemagne sur les prix de CO_2 (allemands) ainsi que l'impact du climat au niveau européen. Nous avons construit les indices de température et de précipitations représentant les deux climats et nous avons analysé l'effet des conditions météorologiques extrêmes et persistantes pour chaque cas considéré séparément.

Les résultats montrent que les variables qui ont un impact majeur sur la variation des prix des quotas de CO_2 sont Brent et le gaz naturel. En outre, il est rendu évident du point de vue statistique que les jours l'extrêmement chauds ou froids en Allemagne ont eu un impact positif sur les prix du CO_2. Toutefois, aucune influence statistiquement significative sur le prix du CO_2 peut être soulevée du charbon (la source d'énergie la plus intensive en émissions), ni de la variable qui représente la possibilité de changer de source de production d'énergie sur la base des prix relatifs entre gaz naturel et le charbon. En outre, toutes les variables statistiquement significatives, présentent un impact sur les prix du CO_2 dans le sens qu'il est prévu. Cela montre une certaine rationalité du marché européen des quotas d'émissions dans sa première année de fonctionnement. C'est-à-dire, le prix du CO_2 à terme reflète des conditions sous-jacentes au niveau micro-économique et, par conséquent, le marché des émissions de CO_2 n'est pas aussi irrationnel, au cours de cette période, comme certains observateurs l'ont suggéré.

En plus d'identifier les variables qui ont eu un de l’'influence sur le prix du CO_2 pendant la première année de négociation, cette étude nous permet également d’analyser les relations entre les variables énergétiques et les émissions de CO_2, ainsi qu’elle permet de clarifier la forme fonctionnelle entre les variables climatiques et de CO2.

Dans ce chapitre, nous ne voulons pas expliquer le niveau moyen des prix de CO_2 par rapport aux expectatives, au cours de la période étudiée, l’objectif étant de centrer notre intérêt sur les variations du prix du CO_2 au cours de 2005. Plus particulièrement, il s’agit d'essayer d’analyser la possible rationalité sous-jacente de la façon dont sont établis les prix du CO_2 pendant la première année de l’EU ETS.

CHAPITRE 3: L’impact des Plans Nationaux d’Allocation des Quotas sur les Prix de CO_2

Le chapitre 3 est intitulé « L'impact des Plans Nationaux d'Allocation des Quotas sur les prix du CO_2 ». Ce chapitre examine l'efficacité du marché à ses débuts. La structure des marchés de quotas et la législation européenne organisant les obligations des États

Membres, fait que la publication d'informations concernant les différents aspects qui peuvent avoir un impact sur les marchés de CO_2, se produit sporadiquement. Parmi ces informations nous pouvons considérer celles (i) liées aux NAPs, documents produits par les États Membres dans lesquels le montant total de quotas disponibles ainsi que son affectation à chaque installation couverte par le EU ETS est établie, et celles liées (ii) aux annonces des émissions réelles vérifiées. Plus précisément, ce chapitre étudie l'impact des annonces officielles faites par la Commission européenne qui concernent la publication des NAPs et la vérification des émissions réelles sur les prix des droits d'émission et de leur volatilité.

La manière dont cette information atteint les marchés européens de CO_2 a certaines caractéristiques qui la rendent attrayante du point de vue des académiques et des participants du marché : elle est sporadique et se produit à de nombreuses reprises. Pour réaliser cette étude, nous avons examiné la période d'Octobre 2004 à Mai 2007, au cours de laquelle plus de 70 annonces ont été enregistrés.

Dans la littérature sur les marchés à terme, il existe de nombreux articles qui utilisent la méthodologie de l'étude d'événements afin de déterminer comment et quand l'information atteindra le marché, dans une grand variété de contextes. Selon McKenzie et al. (2004) dans la littérature deux types d'approches sont essentiellement utilisées. Le premier consiste à estimer les variations de prix anormaux à partir des coefficients d’une régression avec des variables *dummy* qui représentent les jours où l’événement a eu lieu (voir par exemple Christie-David and Chaudhry (2000), Lusk and Schroeder (2002) and Simpson and Ramchander (2004)). La deuxième approche consiste à utiliser le modèle utilisant le *Constant Mean Adjust Retourn model*, avec ce modèle vous obtenez des variations de prix anormaux sur une période de référence (voir Mann et Dowen (1997) et Tse et Hackard (2006)). Dans ce chapitre, nous avons utilisé ces deux approches de la méthodologie de l'étude d'événements en utilisant des variations de prix journalières sur le contrat à terme du CO_2.

Toutefois, les particularités de notre série de données nous obligent à adapter la méthodologie. D'un coté nous sommes face à grand nombre d'annonces très proches entre elles, et de l'autre coté elles ont un impact sur une seule série de prix. Afin de réduire au minimum les grandes surprises qui peuvent avoir lieu dans la période de prédiction quand nous appliquons le Constant Mean Adjust Return Model, nous proposons d'utiliser à sa place, le modèle de moyenne tronqué, qui est une modification du modèle Constant Mean Adjust Return Model, mais qui obtient les variations de prix anormales en utilisant une moyenne.

C'est-à-dire, dans ce chapitre, nous avons adapté la méthodologie traditionnelle de l'étude d'événements appliquée à d'autres marchés financiers d'une part pour répondre à certaines spécificités du marché des émissions de CO_2 et d'autre part, cette adaptation de la méthodologie nous permet de minimiser les fortes surprises au cours de la période de prévision.

Les résultats montrent que les annonces relatives aux plans nationaux d'assignation (à la fois des annonces de la phase I et phase II) ont un effet sur les variations des prix du CO_2 le jour de l'annonce et, dans quelques cas au cours des jours suivants. Cependant, nous avons également détecté d'importantes variations des prix dans les jours précédant l'annonce.

En ce qui concerne l'impact de ces annonces sur la volatilité, nous n'avons pas trouvé d'effet significatif avant ou après l'annonce.

D'après ces deux constatations, la présence de rendements anormaux statistiquement significative jusqu'à trois jours avant l'annonce concernant les NAPs et l'absence d'effets sur la volatilité lorsque l'information est divulguée, indique qu'il y a eu fuite de d'information avant l'annonce.

Ces résultats soutiennent la demande par la European Federation of Energy Traders (EFET, 2006) à la Commission européenne suite à la publication des émissions vérifiées de 2005 qui a eu lieu en Mai 2006. EFET a expressément demandé que les informations importantes qui pourraient avoir un effet sur le prix des émissions de CO_2 soient *exactes, finales, et publiées de manière à ce qu'elles soient accessibles à tous les participants du marché en même temps*.

CHAPITRE 4: Prix de CO_2 et Gestion de Portefeuille

Enfin, le quatrième chapitre est intitulé « Prix de CO_2 et Gestion de Portefeuille ». Comme nous l'avons vu, l'EU ETS est organisée en deux phases. La Phase I a débuté en Janvier 2005 et la Phase II en Janvier 2008. Puisque le transfert de quotas entre les deux phases n'est pas autorisé, les actifs concernant chaque Phase doivent être considérés comme des actifs différents. C'est à dire, les prix à terme venant à échéance en Décembre 2007, ne doivent pas coïncider, et depuis Mai 2006 ne coïncident pas, avec les prix à terme avec échéance 2008. Par conséquent, au cours de la Phase I de l'EU ETS deux types d'actifs qui représentent la permission d'émettre une tonne de CO_2 dans l'Union européenne ont été simultanément négociés. La différence entre les deux actifs est la période de temps pendant laquelle l’émission de cette tonne de CO_2 peut avoir lieu. Notez qu’à partir d’avril 2008 la négociation des EUAs Phase I a complètement cessé et, par conséquent, l'intérêt de l'étude est tout simplement d'observer ce qui s'est passé pendant la phase pilote de l’EU ETS.

Pour ce chapitre il est également important de noter que, comme indiqué dans le premier chapitre, les installations couvertes par la directive 2003/87/EC (les grands émetteurs de CO_2) ne sont pas les seuls participants qui peuvent se joindre à l’EU ETS. Toute personne physique ou morale est autorisée à ouvrir un compte et à participer à la négociation des quotas. Par conséquent, il est intéressant d'examiner si le lancement de l’EU ETS a créé de nouvelles possibilités d'investissement pour les participants qui n'ont pas l'obligation de réduire les émissions et donc ne sont pas obligés d’utiliser l’EU ETS pour atteindre leurs objectifs.

Depuis la publication de l’article de Markowitz « Portfolio Selection » dans le Journal of Finances, en 1952, de nombreux auteurs ont manifesté leur intérêt pour l'étude des avantages de la diversification dans une grande variété de contextes. Par exemple, Grübel (1968) et Eun et Resnick (1988), tentent de montrer si un portefeuille diversifié est préférable en termes de diversification si on considère l’inclusion d’actifs d’autres pays à un portefeuille qui ne les introduit pas (diversification internationale). Dans d'autres cas, les auteurs ont étudié les possibilités de diversification lors de l'introduction de nouveaux actifs. Par exemple, Ibbotson et Siegel (1984), Kuhl (1987) et Chandrashekaran (1999), comparent les fonds d’investissement immobilier (RITS) avec d'autres possibilités d'investissement dans le but d’étudier la capacité de ces actifs pour améliorer la diversification du portefeuille (diversification des actifs). Pour un autre exemple voir des auteurs tels que Jensen et al. (2002), Gorton et Rouwenhorst (2004), et Erb et Harvey (2006), qui analysent l'impact de l'introduction de certains indexes de matières premières telles que le Goldman Sachs Commodity Index (GSCI) dans la gestion de portefeuille.

L'objectif principal de ce chapitre est d'étudier l'effet sur la diversification du portefeuille qui peut être provoqué par l'introduction des EUAs dans un portefeuille diversifié. Les principales raisons pour lesquelles nous pensons que cette analyse est particulièrement opportune sont essentiellement que (i) l'intérêt des investisseurs dans les marchés du carbone est en augmentation constante, et (ii) la Phase I de l'EU ETS vient de se terminer, il est donc possible d'effectuer une analyse sur les conséquences pendant la phase pilote. Plus précisément, dans ce chapitre nous tentons de décrire l'effet de l'introduction de ce nouvel actif dans un portefeuille diversifié au cours de la Phase I de EU ETS. En outre, nous avons analysé les conditions dans lesquelles l'existence des EUAs augmente les possibilités d'investissement pour les investisseurs européens au cours de la Phase II de l'EU ETS. Les résultats sont intéressants aussi bien d'un point de vue académique que pour les participants au marché.

Pour la réalisation de cette étude, nous nous somme intéressés dans un premier temps aux caractéristiques des EUAs Phase I et Phase II en tant que possibles investissements individuels. Nous avons constaté que les rendements des actifs ne sont pas très élevés et qu'ils présentent un écart type assez élevé. De ce fait, les deux actifs ont un faible ratio de Sharpe (c'est notamment le cas de EUAs de la Phase I). Par conséquent, nous pouvons en déduire que ce type de biens, en tant qu'investissement individuel ne sont pas recommandés. Toutefois, si l'on considère que les variations de prix des EUA pour la Phase I ont été fortement négatives, nous pouvons envisager de vendre l'actif.

Ensuite, nous avons étudié l'effet de l'introduction de ces deux actifs séparément dans un portefeuille diversifié, composé d’investissements traditionnels et de variables énergétiques. Parmi les actifs traditionnels nous avons pris en compte des obligations et des actions. En ce qui concerne les obligations nous avons utilisé les prix à terme des actifs les plus liquides en Europe : Euro Schatz, Euro Bolb, Euro Bund qui sont des obligations avec une échéance de 2, 5 et 10 ans respectivement. En ce qui concerne les actions nous avons pris les prix à terme du Dow Jones Euro Stoxx 50. Pour ce qui est des variables énergétiques, nous avons utilisé aussi les plus représentatives en Europe, plus spécifiquement les prix à terme du gaz naturel et du Brent négociés à l’International Petroleum Exchange. Nous avons considérée comme variable libre de risque l’EURIBOR à un mois.

Par la suite, nous avons utilisé tous ces actifs pour construire différents portefeuilles auxquels nous avons introduit les EUAs Phase I et Phase II afin d’étudier l'impact de l'introduction de ces deux actifs dans la variation des prix et la volatilité du portefeuille. Les pondérations des différents actifs que nous avons utilisés pour construire les six portefeuilles sont les suivantes :

- Portefeuille I: 50% d’actions et de 50% d’obligations,
- Portefeuille II: 80% Portefeuille I et 20% de variables énergétiques,
- Portefeuille III: 80% Portefeuille I et 20% de CO_2 Phase I,
- Portefeuille IV: 80% Portefeuille I et 20% CO_2 Phase II

- Portefeuille V: 80% Portefeuille I, 10% de variables énergétiques et 10% de CO_2 Phase I,
- Portefeuille VI: 80% Portefeuille I, 10% de variables énergétiques et 10% de CO_2 Phase II.

Ainsi, en utilisant la méthode de Markowitz (1952), nous avons obtenu la frontière efficiente pour chacun de ces portefeuilles. Nous avons effectué cette analyse en utilisant variations des prix historiques et variations de prix ajustés en fonction du risque pour obtenir les variations du prix espérées. Dans les deux cas, les résultats sont très similaires.

Tout d'abord, nous avons pu constater que l'introduction de quotas de CO_2 de la Phase I ainsi que de la Phase II, peut augmenter l'ensemble des possibilités d'investissement pour les investisseurs qui avaient déjà investi dans des actifs traditionnels (actions et obligations). Toutefois, les possibilités offertes par l'introduction des EUA Phase I dans le portefeuille ont été plus importantes que celles présentés par l'investissement dans des EUAs Phase II pendant la période d'échantillonnage considérée.

Si l'on considère un investisseur qui a déjà une représentation des variables énergétiques dans son portefeuille, l'introduction d'EUAs Phase I aurait permis d'accroître ses possibilités d'investissement Toutefois, quelle que soit la méthode utilisée pour obtenir les variations de prix espérées, le résultat est que le portefeuille qui inclut les variables énergétiques permet d'obtenir des combinaisons de risque-variation des prix supérieures à celle qui contient EUAs Phase II.

Enfin, ce chapitre aborde également la façon d'introduire les EUAs dans le portefeuille optimal pour lequel nous avons fixé un objectif de rendement de 3%, 5% ou 10%. Dans ce cas, les résultats montrent que le poids des EUAs dans le portefeuille optimal n'est pas très important et il est nécessaire, dans la plupart des cas, de permettre les ventes à découvert pour que les EUAs soient introduits dans le portefeuille optimal. Cela est particulièrement le cas lorsque l'on considère les EUAs Phase I, dans laquelle les prix ont fini en 2007 à des niveaux très proches de zéro.

Commentaires finaux

Dans cette thèse nous avons essayé de répondre à certaines des questions qui se posent suite à la création de marchés d'échange de quotas de CO_2. Ces questions concernent essentiellement le fonctionnement des marchés, les déterminants des prix du CO_2, l'évaluation de l'efficacité de ce nouveau marché ainsi que les implications de l'existence de deux nouveaux actifs (EUAs Phase I et EUAs Phase II) dans la gestion de portefeuille. Nous avons essayé de répondre rigoureusement à ces questions qui concernent à la fois les académiques, les participants au marché et les régulateurs.

Puisque les séries de données disponibles lorsque nous avons commencé cette thèse n'était pas très longues (un an de données pour le deuxième chapitre, deux ans pour le troisième et trois pour le quatrième), nous avons utilisé tout au long de la thèse des outils de l'économétrie non-paramétrique ce qui nous a permis d'éviter de faire des hypothèses sur la distribution des variations des prix à partir de CO2. En outre, dans le chapitre 3, nous avons dû adapter la méthode aux spécificités de notre cas particulier et dans le chapitre 4, nous n'avions eu d'autre choix que d'envisager la gestion de portefeuille utilisant EUAs avec un horizon d'investissement à court terme. Par conséquent, l'extension naturelle de cette thèse est d'examiner de plus longues séries en considérant des périodes historiques plus longues. Cela n'est possible qu'avec le développement de l'EU ETS et des autres marchés internationaux d'échanges de quotas. D'autre part, le chapitre 1 doit être constamment mis à jour, surtout si nous tenons compte le fait que la préparation de la phase III de l'EU ETS et les négociations internationales sur le post-Kyoto se développent à l'heure actuelle.

Dans le cas où nous disposerions de séries de prix plus longues, nous pourions envisager d'introduire de nouvelles variables (liés à l'économie et le climat) en tant que déterminants du prix de CO_2. Parmi les variables économiques, nous pouvons étudier si l'évolution du PIB a un impact sur les prix du CO_2 (une augmentation de la production devrait conduire à une augmentation de la demande d'énergie et donc à une augmentation du prix du CO_2). Nous pouvons également envisager le développement d'activités qui visent à réduire des émissions de CO_2 tout en conservant la production. Ces activités seront essentielles dans la fixation du prix d'équilibre dans la Phase II de l'EU ETS. En ce qui concerne les variables climatiques qui peuvent avoir un effet à long terme sur les prix du CO_2, nous pouvons considérer par exemple des éléments tels que le niveau de l'eau dans les barrages (une réduction significative du niveau d'eau dans les barrages pourrait produire une réduction de la production d'électricité hydraulique et donc être déterminant pour l'établissement du prix du CO_2 à long terme). Notez que dans les deux cas, nous sommes en train de considérer des variables qui ont d'importants changements à long terme et ne peut donc pas être utilisées pour analyser les déterminants des prix du CO_2 dans le court terme. Ceci dit, elles sont tout à fait justifiées dans l'analyse des déterminants des prix du CO_2 à long terme.

Veuillez noter que nous avons analysé les déterminants des prix du CO2 du point de vue de la demande. La principale raison est que l'offre dans EU ETS est une décision politique et donc l'importance des politiques publiques liées aux changements climatiques sont aussi l'un des principaux facteurs influant sur le prix du CO2.

En ce qui concerne le chapitre 3, il serait intéressant de s'interroger sur l'existence des annonces non officielles, telles que celles publiées par Point Carbone. Ces annonces peuvent avoir un impact sur les prix de CO_2 car elles sont suivies par un grand nombre de participants du marché. La principale raison pour laquelle nous n'avons pas pris en considération ces annonces dans cette analyse est que nous voulions analyser l'impact des annonces *officielles* sur le prix du CO_2.

En ce qui concerne le chapitre 4, une série de prix plus longue nous permettrait de changer l'horizon temporel de l'investissement et prendre en considération des intérêts à long terme. Des questions comme « *est-il financièrement intéressant pour un investisseur d'investir à long terme dans un actif avec une volatilité élevée ?* » pourrait être analysé avec des séries plus longues. En outre, il serait également possible d'analyser les possibilités de couverture du risque d'inflation ou d'autres variables macro-économiques de ces nouveaux actifs. Ces variables changeant avec des périodes plus longues, nous avons besoin de séries de CO_2 plus longues. Une autre possibilité serait d'introduire les variations des prix du CO_2 en tant que variable explicative dans les modèles d'évaluation des entreprises qui ont des objectifs contraignants de réduction des émissions.

En conclusion nous tenons à souligner que l'EU ETS a réussi à fixer un prix pour les émissions de CO_2. Comme nous l'avons vu, ceci est indispensable à la lutte contre le changement climatique et il s’agit d’un des principaux objectifs du lancement de ce marché. Il est vrai qu’il n’y a pas eu assez de rareté dans le marché européen de CO_2 pendant la Phase I et par conséquent le prix à la fin de cette période était très proche de zéro. Comme prévu, un faible prix ne peut pas encourager une réduction des émissions suffisante. Toutefois, comme indiqué par la Commission Européenne, la Phase I a servi à créer l'expérience nécessaire pour permettre à tous les participants du marché d’atteindre leurs objectifs dans la prochaine phase. De ce point de vue, la Phase I devrait être considérée comme une phase pilote.

INTRODUCTION

Climate change is having an increasing importance in our society. The Intergovernmental Panel on Climate Change in the fourth assessment report entitled "*Climate Change 2007: Synthesis Report*", leads no doubt about the anthropogenic source of Climate Change and urges governments to find a solution to one of the most important global problems of the XXI century.

Additionally, in order to face the consequences of Climate Change, society has incorporated a new concept: ***Carbon Finance***. Following Labatt and White (2006), Carbon Finance explores the financial implications of living in a carbon constrained world, a world in which emissions of carbon dioxide and other greenhouse gases carry a price. The carbon markets are an important part of Carbon Finance but not the only one. The development of projects to reduce greenhouse gas emissions (alternative investment opportunities strategies) or specific government policies are some of the other basic pillars of Carbon Finance.

The importance of establishing a price for carbon emissions is also underlined by the Stern (2006) report in which the author emphasizes that in order to foster an effective, efficient, and equitable response to climate change, price signals and markets for carbon must be created.

The formation of such a price has been motivated by one of the most important global politics to diminish greenhouse gas emissions: the Kyoto Protocol. The protocol came into force on 16th February 2005. This protocol fixes legally biding emission reduction targets to those industrialised countries that have ratified it for the period 2008-2012. However, three flexibility mechanisms are allowed in order to facilitate the compliance of the reduction objectives. Among them we find Emissions Trading (art.17 of the Kyoto Protocol) that has played a crucial role in facilitating the launch of the European Union Emission Trading Scheme (EU ETS). Following Lowrey (2006), although the main objectives of the EU ETS are the reduction of emissions and the promotion of low carbon technologies and energy efficiency, perhaps the most important objective is the establishment of a market price for allowances. This means that European CO_2 emitting installations are aware of the financial consequences of their polluting production.

The EU ETS is the largest environmental market in the world exceeding the US SO_2 trading program in several areas such as the number of installations, and the quantity of emissions covered and the value of assets created and distributed. Under this scheme, officially launched on 1st January 2005, the European CO_2 large emitting installations receive from their government, through the National Allocation Plans (NAPs), allowances for each of the two Phases of the EU ETS (Phase I and Phase II). Those allowances can be traded in several spot, futures and options markets, whenever the installations fulfil their reduction targets at the scheduled time.

The study of the carbon markets is at the heart of finance, and since the start of the EU ETS, the number of academic articles looking at the markets has experienced a huge expansion. However, at the beginning of this dissertation (September 2005), there were no research articles that studied from an empirical point of view the financial behaviour of the European carbon markets. One of the objectives of this dissertation is to fill this gap in the financial literature.

The dissertation is organized in four chapters, each one analysing the European carbon market from a different point of view.

Specifically, chapter 1 is entitled *"CO2 Trading"* and the main objective is to actualise the state of the CO_2 markets. This chapter deconstructs all the singularities of carbon trading and specifically the particularities of carbon trading in Europe. We present the origins of carbon trading, being the Kyoto Protocol, and having emission trading as one of its three flexibility mechanisms. We also illustrate, for those countries that have ratified the Kyoto Protocol, what the possibilities are for reaching their reduction targets and we present the state of compliance of Annex B countries and particularly the European countries. Before describing the EU ETS in depth, we look at allowance trading experiences prior to its launch. Additionally a detailed idea of carbon trading is given both in Europe and in other parts of the world.

Chapter 2 is entitled *"CO_2 Prices, Energy, and Weather"*. The aim of this chapter is to focus on the CO_2 daily returns during 2005. Specifically, we study the effect of those weather and non-weather variables that academic and market agents consider as the major determinants of CO_2 prices. One of the main difficulties of this chapter was the absence of empirical studies in the scientific literature on this matter. There were, however, theoretical explanations for the determinants of carbon prices and articles based on simulations that introduce the impact in the economy of having a price for carbon. Additionally, since the creation of the EU ETS there have been publications by market agent participants about the evolution of European carbon prices, and thus, an idea existed as to which variables could determine carbon prices. The results show that the energy variables are the principal factors in the determination of CO_2 prices, and that only extreme temperatures influence them. Additionally, the study will allow us not only to gain insights into the relationship between energy-related variables and CO_2 prices, but also to shed light on the functional form between weather variables and CO_2 returns.

Chapter 3 is entitled *"The Impact of National Allocation Plans on CO_2 Prices"*. The release of information in carbon markets at its early state has some attractive features for both academics and traders: it is unscheduled, sporadic and numerous. In this chapter we have considered official announcements that are (i) made by the European Commission, (ii) related to the National Allocation Plans (the documents elaborated by Member States where the total cap of allowances is fixed), and (iii) related to the verification of real emissions, in order to analyze their impact on carbon prices and their volatility. We have considered the period from October 2004 to May 2007, during which time more than 70 announcements were released. In this chapter, we have adapted the methodology used for other financial markets from bibliographies for futures markets and we have adapted it to our needs. In particular, to face the specificities of the CO_2 market, and to minimize big surprises during the prediction period, we propose the Truncated Mean model which is a modification of the Constant Mean Adjust Return model in which the abnormal returns in the estimation period are obtained using a truncated mean. The results indicate that news has an influence on carbon prices on both the announcement day and on previous days. Additionally, we find no effects of news on returns volatility. Both findings suggest a systematic leakage of information to the market in almost all types of events.

Finally chapter 4 is entitled *"CO_2 Prices and Portfolio Management"*. In this chapter, we analyse both the characteristics of the EUAs Phase I and Phase II as a sole investment and the impact of including those two assets, considered separately, in various diversified portfolio made up of several combinations of traditional investments, energy variables, and CO_2 Phase I and Phase II. Since the interest of investors in carbon markets is constantly increasing, jointly with the fact that Phase I of the EU ETS has just finished, the moment to study the impact of including those assets in a diversified portfolio is timely. Hence, our first goal is to provide a description of the repercussions of this new asset on portfolio diversification considering Phase I of the EU ETS. As well, we will also analyse under which conditions the existence of these new assets (the EUAs Phase I and Phase II) will enlarge the investment opportunities for a European investor in Phase II of the EU ETS. We have performed this analysis using the Markowitz (1952) methodology. We find that even if the weights of EUAs are not too important when incorporating the EUAs in an optimal and well diversified portfolio, the efficient frontier shows an increase of the investor possibilities. Finally, we find that in most of the cases it is indispensable to allow for short sales.

We would like to add that we have faced two main difficulties during the realisation of this dissertation that apply for all the chapters. The first one is related to the absence of long series of data that have usually limited the study of this market to a short run point of view, making it difficult to obtain results for the long run. This is particularly the case for chapter 2 and chapter 4. In the first case, the availability of data does not allow the introduction of variables such as the state of the economy or other climatologic variables that vary over long periods of time such as the percentage of water in the reservoirs. In chapter 4, the availability of data does not allow the studying of the benefits of portfolio diversification from a long term investor point of view.

The second difficulty has been the absence of a specific bibliography of empirical analyses of carbon markets. Thus, we had to adapt the methodology used in other finance contexts in order to find solutions to the questions about the EU ETS. For example, in chapter 3 we focused on Futures Financial Markets in order to analyse the informational efficiency of the EU ETS, and in chapter 4 we have centred our attention on the bibliography that focuses on the introduction of alternative investments such as the Real Estate Investment Trust in traditional portfolios made up of stocks and bonds.

CHAPTER 1

CO_2 Trading

1.1. INTRODUCTION

Since the ratification of the Kyoto Protocol by a large number of countries, carbon trading has been expanding continuously and thus the interest in studying this new phenomenon. Several previous experiences with emission allowance trading had taken place around the world before the start of the European Union Emission Trading Scheme (EU ETS). However, the EU ETS is, at the present, the largest emission trading scheme not only in terms of installations but also in terms of real emissions considered, and consequently it is important to understand how it is organized. Nevertheless, it is also interesting to consider how it is linked with the other United Nations carbon markets and with the other flexibility mechanisms of the Kyoto Protocol (the Joint Implementation and the Clean Development Mechanism) that lead to other types of tradable allowances (Emission Reduction Units and Certificate Emission Reductions, respectively). The objective of this chapter is to deconstruct all the particularities of carbon trading and, specifically, to analyse the details of carbon trading in Europe.

The remainder of the chapter is organized as follows. In section 2, we present the origins of carbon trading. First of all, we introduce the Kyoto Protocol and emission trading as one of the three flexibility mechanisms established to facilitate the accomplishment of the emission reduction objectives, and thus we explain, for those countries that have ratified the Kyoto Protocol, what the possibilities are for reaching their reduction targets. We also show the state of compliance of Annex B countries and particularly the compliance of the European countries. Finally, we present the allowance trading experiences prior to the launch of the EU ETS. In section 3, the EU ETS is described in depth. Section 4 gives a detailed idea of carbon trading. After we present carbon trading in Europe, we explain OTC, spot, futures and options trading. In section 5, the linking of the European carbon markets with the other United Nations markets and the trading of Kyoto credits is taken into account. Finally, section 6 concludes and makes some final remarks.

1.2. CARBON TRADING ORIGINS

1.2.1. The Kyoto Protocol

The Kyoto Protocol is the international response to climate change. It was approved in the 3rd Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in December 1997 but it did not come into force until February 2005. The reason for such delay was that the Kyoto Protocol had to be ratified by at least 55 Parts of the Convention, including the developed countries representing 55% of their total emissions in 1990. This condition was accomplished when Russia decided to ratify the Protocol and consequently, the Kyoto Protocol finally came into force with the agreement of 141 countries. In addition to those countries, others have studied, approved or will study the Protocol. Note that the largest greenhouse gas emitter, the USA, which represents 25% of total emissions and 40% of developed countries' emissions, has not yet ratified the Kyoto Protocol.[1]

By ratifying the Kyoto Protocol, Annex I countries (those countries in Annex I of the UNFCCC and thus, that have signed the convention) make the commitment to reduce their global greenhouse gases emissions by at least 5% of the emissions in 1990 in the commitment period from 2008 to 2012 (Art. 3 of the Kyoto Protocol). The greenhouse gases, listed in the Annex A of the Protocol, are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and

[1] For updated information on the state of ratification of the Protocol, please see http://unfccc.int/kyoto_protocol/background/status_of_ratification/items/2613.php.

Sulphur hexafluoride (SF_6). Nevertheless, a measure unit, CO_2-equivalent tonnes (CO_2-e), has been constructed in order to indicate the global warming potential of the different greenhouse gases. CO_2 is then, the reference gas against which other greenhouse gases warming potential is measured. Additionally, the Kyoto Protocol emission reduction of 5% is distributed among the Kyoto Protocol Annex B countries and thus it contains legally binding emissions targets for them. The percentage of reduction targets for those countries for 2008-2012 is shown in Table 1. Note that the European Union-15 is considered as a whole in the Kyoto Protocol. European countries have distributed their reduction targets in the burden sharing agreement. The greenhouse gas emission reduction targets for the European Countries are also shown in Table 1.

[Please, insert Table 1].

Note that although the Kyoto Protocol considers only a single commitment phase, in the 11th Conference of the Parties of the Convention, which took place in Montreal in December 2005, a new working group "*was established to discuss future commitments for developed countries for the period after 2012*".[2] Additionally, in the United Nations Climate Change Conference in Bali that took place from the 3rd to the 14th December 2007, a roadmap was established in order to deal with climate change. Among other things, this meeting launched a new negotiation process with the purpose of establishing a post-Kyoto agreement to reduce greenhouse gas emissions around the world. This negotiation process will last until 2009.[3]

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[2] See http://unfccc.int/meetings/cop_11/items/3394.php for further information on the Montreal Conference.

[3] See http://unfccc.int/meetings/cop_13/items/4049.php for more information about Bali's conference.

Kyoto Protocol Flexibility Mechanisms.

With the intention of facilitating the accomplishment of the emission reduction objectives, the Kyoto Protocol establishes three flexibility mechanisms that allow for the diminishment of the overall cost of achieving emission targets. These three mechanisms are the Joint Implementation mechanism (under art.6), the Clean Development mechanism (under art.12), and Emissions Trading (under art.17). The first two mechanisms consist of the execution of emission reduction projects that lead to different types of units. Those units make the holder eligible for compliance with the reduction obligations. Each unit allows for the emission of one metric tonne in CO_2-e terms.

Specifically, the Join Implementation mechanism (JI) consists of the realization, by an Annex I country, of emissions reduction projects in another Annex I country. In return JI projects lead to Emission Reduction Units (ERUs) that can be used by the Annex I country promoting the project to meet its emissions targets under the Kyoto Protocol.

The purpose of the Clean Development Mechanism (CDM), as explained in the Kyoto Protocol, *shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance.* The idea is the same as JI but instead of implementing the project in an Annex I country it is implemented in a developing country. In this case, units called Certified Emission Reductions (CERs) are generated and will be used by the Annex I country to achieve compliance. In the CDM projects the achievement of sustainable development for non Annex I countries is as important as the reduction units generated by the projects. The CDM projects have to be approved by the Executive Committee of the CDM Board for projects (which is the institution that issues the CERs). It is important to note that although the Kyoto Protocol does not impose emission reduction commitments on developing countries, those countries play a crucial role in global emission reductions by means of the Clean Development Mechanism of the Kyoto Protocol. As Lecocq and Ambrosi (2007) pointed out, the development of this mechanism in terms of countries involved and volumes of emission reductions is very important and it is in constant expansion. As a result, the purpose of this mechanism is largely attained for both types of countries. However, those projects that allows for significant gains in terms of emission reductions are not always those that allow for higher growth in the regions where the project is undertaken.

The third flexibility mechanism, the Emission Trading mechanism, offers the possibility to trade all different units among countries. In addition to ERUs and CERs, other types of units can be used in order to achieve compliance with the Kyoto Protocol. Among those units we find on the one hand, Assigned Amount Units (AAUs) that are received by the governments of each country depending on its fixed target, and on the other hand, there also exist Removal Units (RMUs). These types of units are issued on the basis of land use, land-use change and forestry activities, they are often referred to as “sinks” and, although they are also eligible for compliance, they are not traded even in the case where they are issued from a project. Finally, there exists another type of tradable allowance. We are talking about Verified Emissions Reductions (VER). The particularity of those units is that they cannot be used by the countries to achieve compliance with their Kyoto Protocol targets. These units are issued from projects that may or not follow the CDM projects requirements and they are traded in the voluntary market. Following Taiyab (2006), the voluntary market consists of companies, governments, organisations, organizers of international events, and individuals taking responsibility for their carbon emissions by voluntarily purchasing carbon credits. This is generally done through companies that invest in projects (not necessarily CDM projects) and that sell small amounts of VER. In this case, the project developers have more freedom to invest in small-scale community based projects, lending for important benefits in terms of, for example, local economic development or biodiversity.

In Figure 1, the relationship among the flexibility mechanisms of the Kyoto Protocol is presented.

[Please, insert Figure 1].

Additionally, in the squares with small dots, we find the description of the European Union Emission Trading Scheme (EU ETS) integration under the emissions trading mechanism of the Kyoto Protocol.[4] This picture shows that all units can be used for compliance or traded among countries and/or companies.

The Registry Role.

The main condition for an Annex I country to be able to trade the different tradable units is to be eligible. The exact meaning of being eligible is that the specific country is able to use international emissions trading under Article 17 of the Kyoto Protocol. Once fully eligible, an Annex B country can transfer, acquire or use ERUs, CERs, and AAUs in order to achieve its targets. One of the requirements to be eligible is to establish a registry where the Assigned Amount Units, the net position in the emissions markets and the units achieved by means of CDM and JI projects are registered. The balance of this registry will be compared to the real emissions of the country in order to determine if there has or has not been commitment of the Kyoto objectives. At the end of the

[4] The EU ETS will be described in section 1.3.

period, each country would surrender and cancel the number of permits that equals its real emissions. Note that banking allowances (the transfer of allowances from one year to the year after) between the years of the commitment period (2008-2012) is allowed by the Kyoto Protocol. Thus, the Kyoto inventory system for each country can be mathematically expressed as follows:

$$R = AAU + ERU + CER + P - S + RMU + B \begin{cases} \geq E \Rightarrow Commitment \\ < E \Rightarrow Penalty = P*(E-R) \end{cases}$$

Where R is the balance of the allowances register, P represents the Purchases in the allowance market, S is the Sales, B is the result of banking, and E is the verified emissions. A government's possibilities to have allowances are reflected by the variables in the left hand side of the equation. On the right hand side of the equation we find the real emissions. Consequently, there is commitment with the Kyoto Protocol only in the case where $R \geq E$. If there is no-commitment with the Kyoto Protocol, the country will have to pay a penalty for each extra CO_2-e tonne emitted. All trades are supervised by the International Transaction Log (ITL) which is the central administrator and guarantees the realization of all trades under certain criteria. The ITL went live on 14th November 2007 and thus, it has been ready since the beginning of the Kyoto compliance period.

The UNFCCC publishes actualized data on the Greenhouse Gas inventories for Annex I countries. The latest report consists of the inventories for the year 2005. In Figure 2-A the Kyoto Target for Annex B countries, the change in real emissions between 1990 and 2005 in percentage terms and the distance to the Kyoto Protocol Target, also as a percentage, are shown. In Figure 2-B the same variables are shown for the European countries.[5] In all cases we present the greenhouse gas inventories without considering land-use, land-use change and forestry.[6]

[Please, insert Figure 2].

The situation of the different non-European Annex B countries referring to the challenges of the Kyoto Protocol is very different (Figure 2-A). On one hand, there are some countries such as Canada, New Zealand and Liechtenstein that have increased their emissions by more than 20% within the period 1990-2005. At the other extreme, Ukraine has reduced its emissions by more than 50% compared to its base year. If we have a look to the European Countries (see Figure 2-B), we see that countries such as Spain, Portugal, Greece, and Ireland have increased their emissions by more than 20%. On the other side, countries such as Rumania, Bulgaria, Estonia, Lithuania and Latvia have reduced their emissions by more than 40%.

The main conclusion is that the Annex B countries with economies in transition had drastically reduced their emissions while the rest of countries had increased them. The case of Spain is particularly complex. Its target is to increase its emissions by a maximum of 15% of 1990 emissions but the increase was already 52.3% in 2005. Although the difference between the Spanish verified emissions and its target is one of the largest ones, Spain is not one of the biggest polluters in the world. Countries such as the USA, Russia, Germany, Japan, among others, emit more CO_2-e per capita than Spain.

[5] Note that the real emissions of Turkey are not presented as they are included in Annex I countries but not in Annex B countries.
[6] See http://unfccc.int/ghg_emissions_data/items/3800.php for updated information on Greenhouse Gas inventories.

Another possible analysis consists of comparing the change in the real emissions with the Kyoto Protocol target of each country. We have created a new variable called "Distance to commitment of Kyoto Protocol" which is the difference between the increase in the real emissions and the Kyoto target. A negative result in this variable, means that the country has emitted less greenhouse gas during the period 1990-2005 than its Kyoto objective. This type of country is a potential seller of CO_2-e allowances. On the other hand, a positive result of the subtraction must be interpreted as the country having exceeded its target. The countries in that situation, such as Spain, Austria, and Luxemburg, are potential buyers of CO_2-e allowances.

In Figure 2-A and Figure 2-B, we can see clearly that the countries that have drastically reduced their emissions (on the left hand side of the graph) are those that have better fulfilled their commitments and even have a wide margin to participate in the international emissions trade as sellers of allowances. On the other hand there are other countries, such as Spain, that have considerably increased their emissions from 1990 to 2005 leading to a deficit of allowances for these countries.

1.2.2. Previous Allowances Trading Experiences

Before the implementation of the Kyoto Protocol and the first use of the trading allowances mechanism, there have been many other experiences with trading different types of allowances.

In the United States, there have been programs to reduce the use of lead in petrol (inter-refinery trading was allowed and also banking), to control Acid Rain (the main objective of the program was to reduce sulphur emissions from power plants in the United States), and to help control emissions of SO_2 and NO_x (the regional clean air incentives market program known as *Reclaim* was established in Los Angeles). Finally, California's South Coast Air Quality Management District's objective is to reduce emissions from business and industries.[7]

There are also trading schemes related to the emissions of acid precursors in Europe. For example, The Netherlands and Slovakia, have legally binding emission caps of acid precursors and, in order to help them to meet their targets, they have introduced trading schemes. For example, in the case of Slovakia, the tradable allowances market started in January 2002. The objective of the program is to reduce the SO_2 emissions in 2010 to 36% of the emissions in 1999. The permits are grandfathered (the allocation is based on the historic emissions of each concerned company) from the central government (Environmental Ministry) to the districts and then to the companies. The penalty in case of polluting more than assigned is about 140 euros per excess tonne. In the UK, there is a trading system on the packaging waste. To fulfil the European legislation, the UK Government has created the packaging recovery note (PRN) to verify that companies do packaging. In fact, the PRNs are traded as a form of evidence of having met packaging obligations and are presented to the relevant agency.

Additionally, due to the interest in promoting renewable energies in Europe, the White Paper for a Community Strategy and Action Plan, published in November 1997, established that a percentage of the energy produced might come from renewable sources. In that context, some countries, including Italy, the Netherlands, Sweden, the United Kingdom, Finland, and Denmark have created tradable renewable energy certificates. The objective is that a plant that produces a bigger percentage of renewable

[7] See http://www.epa.gov/airmarkets/progsregs/arp/index.html for further information about the US acid rain programme, http://www.aqmd.gov/reclaim/reclaim.html for information about the US *Reclaim* program, and http://www.aqmd.gov/ for further information about California's South Coast Air Quality Management District program.

energy can sell to another plant a part of that percentage to allow the latter to meet its commitments.[8]

Trading has also been used in other contexts where resources are vulnerable to human activity. An example of this is the individual transferable quotas in fisheries, which are used in New Zealand, Canada, Iceland, the Netherlands, the UK, Denmark, Portugal and Italy.

Related to climate change and before the creation of the EU ETS, the UK created a trading scheme, the UK greenhouse gas emission trading scheme, which is part of the UK climate change programme. The UK emissions trading scheme was launched in March 2002 and ran until December 2006, with final reconciliation in March 2007. Thirty-three organisations ("direct participants" in the scheme) voluntarily took on emission reduction targets to reduce their emissions against 1998-2000 levels. They committed to reducing their emissions by 3.96 million tonnes of CO_2-e by the end of the scheme.

The Danish CO_2-e emission allowance scheme, a cap and trade system designed and operated by the Danish Energy Agency, started in 1999 and covered the large electricity producers in Denmark. The nine largest emitters in the electricity-generating sector represent more than 90% of the total CO_2-e emissions from that sector, and approximately 30% of total Danish GHG emissions. The initial permits were allocated to firms according to their historical GHG emission levels between 1994 and 1998 and a penalty of DKK 40 (~EUR 5.30) was applied for every metric tonne of CO_2-e that was emitted beyond a given firm’s individual cap. The scheme has been superseded by the new European greenhouse gas emission allowance trading scheme from January 2005.

[8] The white paper was published in the European Commission communication COM(97)599. It can be found at http://www.managenergy.net/products/R26.htm.

In Australia, under the New South Wales Greenhouse Gas Abatement Scheme, from 1st January 2003 and with the objective of reducing greenhouse gas emissions to 7.27 tonnes of CO_2-e per capita by 2007, electricity retailers and other parties were required, by legislation, to meet mandatory targets for reducing the emission of greenhouse gases associated with the production and use of electricity. To achieve the required reduction in emissions, eligible parties purchase and surrender tradable certificates called New South Wales Greenhouse Abatement Certificates. Each year, the Scheme sets individual benchmark reductions of greenhouse gas emissions for each participant based on their contribution to the supply of electricity. In the case that the participant emits more CO_2-e than its objective a penalty of AUD 10.50 per tonne of CO_2-e above its benchmark must be paid.[9]

Most of the programs commented above are widely studied in the European Environment Agency (EEA) technical report nº 8/2005: "Market-based instruments for environmental policy in Europe", the EEA technical report nº 1/2006: "Using the market for cost-effective environmental policy" and they are also analysed by Boemare and Quirion (2002). Specifically, Boemare and Quirion (2002) comment on some similarities and differences among programs and try to find out which are the lessons to be applied in the EU ETS. For example, they confirm that most of the programs work with registration transfers and allow the banking of allowances, they consider monitoring and effective sanctions as crucial mechanisms in the success of a program and they underline that the US Acid rain program had lower costs than the most

[9] For further information, please see http://www.greenhousegas.nsw.gov.au/.

optimistic forecast. The authors also study the case of two companies, BP and Shell that had established trading systems to reduce their emissions.[10]

As commented before, apart from the schemes created in order to facilitate the achieving of the objectives of reducing greenhouse gas emissions under the Kyoto Protocol, another phenomenon related to carbon credits has started recently. We are talking about the *voluntary market*. The Chicago Climate Exchange (CCX) has organized a voluntary trading scheme in the USA. CCX emitting members make a voluntary, but legally binding, commitment to meet annual emission reduction targets of all six major greenhouse gases. The trading of CCX Carbon Financial Instrument (CFI) contracts facilitates the compliance.

1.3. THE EUROPEAN UNION EMISSION TRADING SCHEME

The EU ETS is the application of the third flexibility mechanism of the Kyoto Protocol at the European level. The scheme officially started 1st January 2005 and it is divided in two Phases. Phase I corresponds to the period starting 1st January 2005 and finishing 31st December 2007, and Phase II coincides with the Kyoto Protocol commitment period and consequently goes from 1st January 2008 to 31st December 2012. The Phase III will probably start on 1st January 2013 and finish in 2020. The EU ETS is one of the most important policies at the European Union level to achieve compliance with the Kyoto Protocol. The EU ETS is the largest emission trading scheme not only in terms of allowances distributed but also in terms of the number of installations covered.

The EU ETS is a Cap and Trade system, in the sense that total emissions are limited or 'capped' and the excess allowances can be traded. However, as it will be linked to the

[10] For further information on the BP trading System see Victor and House (2006), and on Shell and BP see http://www.environmental-finance.com/2003/0302feb/bpshell.htm.

United Nations carbon markets, the EU ETS will allow for more permits (ERUs and CERs) to enter into the system. It is regulated by the 2003/87/EC Directive, amended by the Directive 2004/101/EC.

As pointed out by Kruger et al. (2007), it is halfway between a wholly centralized and a completely decentralized system. On the one hand, the central administrator, the European Commission, decides the structure of the scheme, the participants in the market, and the gases whose emissions should be reduced. On the other hand, the Member States fix, through the National Allocation Plans (NAPs) approved by the European Commission, the national cap, and they allocate the emissions cap among the installations covered by the 2003/87/EC Directive. Additionally, the monitoring, the verifying of real emissions and the reporting of the national compliance of the Kyoto Protocol is also done by Member States who must punctually inform the European Commission. Member States also decide about the way the allowances are distributed and the possibility of banking allowances among Phases.

Not all the sectors in the economy producing CO_2 emissions are regulated by the 2003/87/EC Directive and thus, not all of them participate in emission trading. In fact the Directive applies to those companies belonging to the following activities: combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, brick, ceramics, pulp and paper. Those sectors are called trading sectors and are different from the non-trading sectors (such as the residential and transports sectors). The distribution of the different sectors in the economy into trading and non-trading sectors is susceptible to changes. For example, at the moment, discussions are taking place in order to decide if aviation will be included in the trading sector and if so, how it would be regulated. Note that in all cases, even if the compliance of the trading sectors is assured by companies and the compliance of the non-trading sector by Member States, the final parties responsible for meeting the obligations are the Member States. As the Member States are responsible for all the emissions in the country, and the Kyoto objective is considered in global terms, they should allocate only a part of their total Assigned Amount Units.

If we come back to Figure 1, we are now in a condition to understand the compliance of the Kyoto Protocol by the European Union countries. As we can appreciate in this figure, the companies under the Directive only used, in order to achieve compliance of their target reduction during 2005-2007, the EU ETS. This is explained by the fact that Phase I of the EU ETS was over-allocated and thus EUA prices were very low, making inefficient the use of other units of the Kyoto Protocol (ERUs and CERs) to achieve compliance in Phase I. Note that in theory, it was also possible for Phase I of the EU ETS to use the other two flexibility mechanisms because the ITL was already launched. However, from January 2008, it will probably be efficient to use CERs and ERUs for compliance. Note that both the ERUs and CERs can be obtained by the companies either through the realisation of projects or via the secondary market.

1.3.1. The National Allocation Plans

Following the 2003/87/CE Directive, the allocation of allowances is done through the NAPs and thus this is the “cap” part of the EU ETS. Each Member State in the EU has to submit its NAP to the European Commission for each of the Phases considered in the Directive. The elaboration of the NAP requires that each Member State must decide ex-ante how many allowances to allocate in total for a trading period. It has also to decide how many allowances each plant covered by the Emissions Trading Scheme will receive per year of the compliance period. The 2003/87/CE covers over 11.500 energy-intensive installations across the EU, which represent close to half of Europe's emissions of CO_2. The allowances distributed to the companies covered by the 2003/87/EC in the EU ETS are called European Union Allowances (EUA). Each EUA allows for one tonne of CO_2–equivalent to be emitted.

The Directive establishes that a minimum of 95% of the total allowances allocated must be freely allocated for Phase I. This percentage is reduced to 90% for Phase II. The other 5% (10%) is auctioned. Nevertheless this is only a lower limit and it is incumbent on each Member State to determine the exact amount of allowances freely allocated and how it proposes to allocate them.[11]

The NAPs has to be presented to the European Commission at least 18 months before the start of the Phase. Upon receipt of a complete plan, the Commission has 3 months for its assessment. All Phase I NAPs were submitted to the European Commission during 2004 and 2005 by all Member States. The European Commission adopted decisions on all countries' plans. Member States had to submit their Phase II NAPs to the Commission by 30 June 2006, including the limitation in percentage terms of the surrender limit for JI/CDM credits.

By early September 2007, all Phase II NAPs had been provided to the European Commission and on October 2007 all the European Commission Decisions were already published. Only in the cases of Denmark, France, Slovakia and the United Kingdom did the Commission respect the cap proposed by the countries. In all other cases the cap was reduced. In the case of 11 countries (Austria, Belgium, Finland, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, Spain, and Sweden) the cap was reduced by less than 10%. However, there are countries such as Lithuania, Latvia, and Estonia

[11] See Ellerman and Buchner (2007) for a discussion on the Allocation process.

where the cap was reduced by around 50% from the amount proposed by the country. The rest of the countries' caps were reduced by between 60 and 85%.

The total allowed cap is around 11% less than initially proposed by the countries. Note that in the case of Phase II NAPs, the European Commission takes into account the 2005 real emissions when deciding about the national caps. The sum is 74.3 million tonnes of CO_2-e per year less than 2005 verified emissions. In order to show the interest of the European Commission in reducing European greenhouse gas emissions, we point out that the European Commission has allocated for Phase II 216.67 million tonnes of CO_2-e per year less than the allocations for Phase I.[12] Table 2 presents the assessments of the European NAPs.

[Please, insert Table 2].

In order to present a graphical idea of which countries represent the largest part of the allowances distributed, we have elaborated Figure 3.

[Please, insert Figure 3].

As we can appreciate in Figure 3, six European countries represent more than 65% of the total allowances distributed in Europe. The most important country in this sense is Germany (22%), followed by the UK (12%). Poland, Italy, Spain, and France are the countries that follow. As we may expect, those are also the countries with the highest verified emissions for the year 2005.[13]

[12] In order to make the amount allocated in Phase I and Phase II comparable, 216.67 does not take into account the Phase II caps for Romania and Bulgaria. The reason for such choice is that those countries did not have Phase I NAPs.
[13] In the third chapter of the dissertation the impact of the publication of information related to NAPs will be studied in detail.

1.3.2. The Trading System

As in the case of the Emission Trading mechanism under the Kyoto Protocol, the EU ETS is organized into accounts transactions. Each Member State has its own registry where the balance of the allowances of each company is captured.[14] For the moment the different registries are linked to the Community Independent Transaction Log (CITL). The CITL oversees the European registry systems that are standardized under European legislation. Its mission is to verify each deal done in the European market. If it finds an irregularity, the trade will not take place until the irregularity has been solved. Nevertheless, all registries will be linked to the United Nations carbon markets and will be integrated in the international registry system under the Kyoto Protocol (the ITL). The European Commission has established April 2009 as the deadline for the European registries to be linked to the ITL. At this moment, the European countries will be eligible to use the credits from the JI and CDM in order to achieve compliance. The European registers already linked to the ITL are those of Austria, Czech Republic, Hungary, and United Kingdom. Additionally, the registries from Japan, New Zealand, and Switzerland are also linked to the ITL.[15]

As the trading is a purely electronic system and as allowances are reflected in accounts, in order to participate in the organized emissions allowance market it is necessary to have an account in the market where the transaction will take place. In that market register, the purchases and sales for each participant are shown. It is important to note that not only the companies covered by the 2003/87/EC Directive are able to participate

[14] In March 2008 there were still 2 registries offline (Bulgaria and Romania). For updated information about the registry status see http://ec.europa.eu/environment/ets/registrySearch.do.

[15] For more information, see the press release "Kyoto Protocol Parties move closer to trading emission allowances" Vienna, 30 August 2007 on the United Nations Framework Convention on Climate Change web page.
http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/070830_press_rel_itl.pdf.

in the organized market. Every natural and legal person is authorized to open an account and participate in the emissions market.

1.3.3. Monitoring of Compliance

To supervise the commitment of the objectives, the European Community has established that each Member State must supervise the submission of a satisfactory emissions report of the previous year's verified emissions by each operator not later than 31st March of the following year. For example, the 2005 verified emissions report must be presented by 31st March 2006. If this report is not presented or if it is not considered satisfactory, the company will not be able to proceed to new trades until this condition is satisfied. Additionally, each company must surrender the allowances of the previous year not later than 30th April of the following year so that they are cancelled. For example, 30th April 2006 was the deadline to surrender the allowances of the year 2005. Figure 4 depicts this process graphically.

[Please, insert Figure 4].

In the case the allowances are not surrendered a penalty of €40 (€100) would be applied in Phase I (Phase II) to the company for each extra CO_2-e tonne emitted. In order to differentiate the emissions trading from a tax on CO_2-e emissions, the penalty of €40 (€100) is a penalty with restitution which means that the payment of the penalty does not release the company from presenting the allowances corresponding to its emissions. The "*payment of the excess emissions penalty shall not release the company from the* *obligation to surrender an amount of allowances equal to those excess emissions when surrendering allowances in relation to the following calendar year*”.[16]

As indicated in the 2003/87/EC Directive (art. 13), the member state must cancel the allowances *that are no longer valid and that have not been surrendered and cancelled*. The Phase I allowances are no longer valid four months after the beginning of the first five-year period (the Phase II of the EU ETS), which means that they are cancelled 30th April 2008 and they are no longer valid in May 2008. The Directive allows the Member States to replace those cancelled allowances with valid allowances. That is, the Directive allows banking between periods and gives the Member States the responsibility to decide if banking is possible in practice. Among all Member States only France and Poland decided to allow banking at the beginning, although France later renounced it. Therefore, in general, the companies cannot do banking between Phase I and Phase II of the EU ETS (between the years 2007 and 2008) and no one expects the existence of banking in the future.

Related to borrowing between Phases, it is generally not allowed, even though we have seen that it depends on Member States. However, the structure of the EU ETS and particularly the penalty with restitution leads to the existence of implicit borrowing between these two Phases. The implicit borrowing is produced if there is no compliance in the last year of Phase I (2007). That is, the number of allowances surrendered in 2008 that corresponds to the real emissions in 2007 is smaller than the verified emissions. In this case, the company has the obligation to pay the penalty and make restitution of the right number of allowances. As this information is known after 30th April 2008, and thus, after the allowances of the Phase I have been cancelled, the only possibility is that

[16] Article 16(4) of the 2003/87/CE Directive.

the restitution of the allowances after the penalty is done with allowances from the next Phase.[17] Consequently, in this case there exists implicit borrowing between Phases. Nevertheless, as we will see in the next section, Phase I allowances finished the Phase I period at a price around zero and thus there was no interest in borrowing between Phase I and Phase II of the EU ETS (note that Phase II EUAs prices were around 20 euros in March 2008).

1.3.4. Post 2012 EU ETS

Before finishing with this part of the chapter, we should just add that the European Commission has made a proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC in order to improve and extend the greenhouse gas emission allowance trading system of the Community.[18] The main amendments concern, on the one hand, the emissions reduction objectives of the Community, and on the other hand, the methodology to distribute the allowances among the installations. Related to the first group the objective reductions are *at least 20% below the 1990 levels by 2020, and 30% provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries contribute adequately according to their responsibilities and respective capabilities.* With respect to the method for distributing the allowances, auctioning will probably be used the most.

In contrast to Phase I and Phase II of the EU ETS, from 2013 onwards, *the basic principle for allocation should be auctioning, which is the most economically efficient system*. Finally, *the allowances issued from 1 January 2013 onwards shall be valid for*

[17] Article 13 (2-3) of the 2003/87/EC.
[18] 2008/0013 (COD).

emissions during periods of eight years beginning on 1 January 2013. Thus we may expect that the EU ETS will continue in Phase III from 2013 to 2020.

1.4. CARBON TRADING IN EUROPE

In this section, we focus our attention on the different possibilities of trading EUAs in Europe. The possibilities vary from Over-The-Counter (OTC) to organized markets trades. In both cases a wide variety of contracts are used. Note that as has already been said, banking is not allowed between Phase I and Phase II of the EU ETS and, consequently, there exist in Europe two differentiated assets that can be traded in the EU ETS: EUAs Phase I and EUAs Phase II. As we will illustrate, this difference is significant. This fact will be important in chapter four of this dissertation.

It is important to highlight that in those markets there are a wide variety of participants. Thus there are industrial agents that are directly concerned with the CO_2 emission reductions, brokers and finally, financial institutions, among others.

1.4.1. Over-the-Counter trading

The first carbon trades in Europe were OTC trades that took place even before the start of the EU ETS. The European Energy Exchange (EEX) soon calculated an index of OTC forward carbon prices, called *CO_2 Index* or *European Carbon Index*. This index was published on each trading day from 25th October 2004 to 30th November 2005. The index was a volume-weighted average price of OTC forward trading activities of market participants with delivery until 30th April 2006. Additionally, other OTC carbon indexes have been created by the London Energy Brokers' Association (LEBA).[19]

Specifically LEBA also calculates three indices. The first one, the *LEBA Carbon Index*, is calculated every trading day using the volume weighted average of EUAs trades transacted by LEBA member firms and takes into account all carbon deals transacted with delivery on 1st December 2007, 1st December 2008, and 1st December 2009. The second one is the *LEBA 0800-1000 Carbon Index* which takes into account all carbon deals transacted with delivery on 1st December 2007, 1st December 2008, and 1st December 2009 between 8 a.m. and 10 a.m. Finally, the *LEBA Carbon Index Spot* takes into account all carbon deals transacted with delivery on spot 1st December 2006, 1st December 2007, and 1st December 2008. The *LEBA Carbon Index*, the *LEBA 0800-1000 Carbon Index*, and the *LEBA Carbon Index Spot* have been published since 30th May 2005, 1st November 2005 and 18th January 2006, respectively.[20]

We have compared in Figure 5-A the European *CO_2 Index* from EEX with the *LEBA Carbon Index Spot* (LEBA(I)), and the *LEBA Carbon Index* (LEBA(II)).

[Please, insert Figure 5].

If we compare the EEX Carbon Index, which refers to prices traded for Phase I of the EU ETS, with the LEBA (I), which also represents Phase I prices, we can appreciate that both prices behave really similar. The prices started at about €6 before the beginning of the EU ETS and in January 2005, when the EU ETS was launched, they were around 8 €/tCO_2. They stayed relatively stable until February 2005. Then the prices increased reaching a peak (29.10 €/tCO_2) on 11th July 2005. The prices decreased

[19] The LEBA is comprised of 10 members who provide coverage for all key product groups in the energy sector: oil, gas, power, coal and emissions.

[20] See http://www.leba.org.uk for further information on the LEBA members and index.

and stayed in the 20-25 €/tCO_2 range until December 2005 when a bullish period started. Another peak was reached on 19th April 2006 when OTC Phase I forward prices were above 30 €/tCO_2. Successive decreases brought the carbon prices to the range 15-20 €/tCO_2. On 15th September 2006 a decreasing tendency started that would not stop until the end of the publication of the Carbon Index (30th November 2006). On 7th November 2006 the OTC Phase I forward prices definitively dropped below the 10 €/tCO_2 barrier and on 3rd April 2007 the barrier of 1 €/tCO_2 for the first time by the LEBA (I), which was traded until 30th November 2007 at 0.04 €/tCO_2.

The LEBA (II) prices publication started 1st December 2006 at a level of 18.89 €/tCO_2, and its evolution was similar to the Phase I OTC prices until 21st December 2007, when a bullish period started. Those prices reached a peak 4th June 2007 of 24.60 €/tCO_2 while Phase I prices were at a level of 0.29 €/tCO_2. Since then the OTC Phase II prices have moved in a range between 20 and 25 €/tCO_2.

1.4.2. Trading in Organized Markets

The organized markets in Europe started with the EU ETS. The European Commission considers that the number of markets trading EUAs should be appropriate from the point of view of the agents participating in them. This means that each country can create its own market or that different platforms of trading can be organized. Therefore, although there is a unique European emissions market from the point of view of what is being traded, the trade can be done through different markets around Europe. In all those markets the underlying asset is the EUA (Phase I and Phase II) but the contracts that can be traded are slightly different.

There exist several organized market places in Europe where it is possible to trade EUAs. Specifically, EUAs can be traded in spot markets such as BlueNext (Paris), Energy Exchange of Austria (EXAA, Vienna), Nord Pool (Oslo), European Energy Exchange (EEX, Leipzig), and Gestore Mercato Elettrico (GME, Rome).[21] There is also a pan-European platform called Climex Alliance where it has been possible to trade spot contracts since July 2005. Furthermore, Nord Pool, European Climate Exchange (ECX/IPE, London) and EEX (jointly with Eurex since 5th December 2007, Eurex/EEX) have listed futures contracts with EUAs as the underlying commodity and BlueNext will launch the EUAs Future contract in a near future. Note that in all carbon futures markets, there are listed futures contracts for Phase I and Phase II of the EU ETS with the exception of BlueNext that will launch this type of contract once Phase I is already finished and, consequently, it will only list Phase II futures contracts.

In spite of the fact that the EU ETS started on 1st January 2005, the first trade in an organized market took place on 11th of February 2005 and it was a futures contract in Nord Pool. The first spot contract was traded in EEX in March 2005. It is important to note that the only possibility for spot trading during Phase I of the EU ETS, that is, during the years 2005 to 2007, was Phase I EUAs and that it was impossible to trade spot Phase II EUAs. The explanation is that without the Phase II allowances delivered, no Phase II EUAs spot trade can take place, and the allowances can not be delivered before the Member States have been granted final approval of their installation-level allocation plans.

[21] Note that BlueNext was a part of Powernext at the beginning of the EU ETS. The Powernext's Extraordinary General Assembly on 21st December 2007 ratified the purchase of Powernext's environmental activity, Powernext Carbon and Powernext Weather, by NYSE Euronext. These environmental activities are now housed within BlueNext, an entity created with Caisse des Depots.

The European Commission fixed the 28th February 2008 as the deadline to allocate the allowances among the companies. However, as reported by Reuters (28th February 2008) only 2 countries met the European commission deadline of 28th February and were able to distribute their allowances: Austria and Denmark. Additionally, as pointed out by Tendance Carbon, only less than 3% of the total allowances were allocated by 28th February 2008.[22]

The first spot trade for Phase II in the EU ETS took place in BlueNext on 26th February 2008. Nord Pool will launch spot trading for Phase II EUAs on 15th April 2008 while Phase I EUAs will be interrupted in this market on 31st March 2008. Additionally, EEX will launch Phase II spot trading in June 2008 (Point Carbon 7th March 2008).

Finally, on 13th October 2006, the ECX launched the first option contracts in an organized market.[23] The alliance Eurex/EEX also launched a EUAs option contract on 14th April 2005.[24] It is important to underline that all those markets are based on accounts transactions, and thus it is compulsory to have a registry in the specific market in order to participate in it. Remember that any natural or legal person is allowed to open an account in those registries.

<u>Spot Contract Characteristics and Price Evolution.</u>

The spot contract that can be traded in the different markets is very similar. In all markets the delivery is physical (there is a transfer from one account to another) and takes place between 24 and 48 hours later. The unit of the contract is always one EUA

[22] See http://bluenext.eu/fic/000/032/248/322485.pdf, for the complete Tendance Carbon num. 23, March 2008.

[23] For additional information about these markets see the official web pages of the carbon markets in Europe: BlueNext (www.bluenext.eu), EXAA (http://en.exaa.at/), EEX (www.eex.com/en), ECX/IPE (www.europeanclimateexchange.com), Nord Pool (www.nordpool.no), CLIMEX (www.climex.com) and GME (http://www.mercatoelettrico.org).

[24] For more information on this news, see http://www.eurexchange.com/about/press/press_562_en.html.

but the size of the contract differs from one market to the next. In BlueNext and Nord Pool the minimum size of the contract is 1000 tonnes of CO_2-equivalent while for EXAA and EEX the minimum size of the spot contract is only one tonne of CO_2-e. In GME the minimum size of the spot contract is 500 tonnes of CO_2-e. The minimum tick in all cases is €0.01. With the exception of the EXAA, where the trade is only once a week, in the other spot markets the trade is from Monday to Friday. Panel A of Table 3 collects the main characteristics of each spot market.[25]

[Please, insert Table 3].

Additionally, we present in Figure 5-B the evolution of spot prices. We can appreciate the evolution of all spot price series has been really similar to the evolution of the Phase I OTC forward prices. This means that independently of the market used, the prices for the Phase I of the EU ETS had been homogenous all around Europe. In our sample period, there are only four days of trading spot Phase II, and the levels are similar to those of Phase II OTC forward prices.

Futures Contracts Characteristics and Prices Evolution.

The similarities of the futures contracts that can be traded in the different European markets are absolutely the same in terms of contract size (1000 tonnes CO_2-e), minimum tick (€0.01), and trading days (from Monday to Friday). However, the ECX offers much more variety for expiry contracts dates. Eurex/EEX offers only December futures contracts for each of the EU ETS years (Phase I futures contracts are those of December 2005, 2006 and 2007 and Phase II futures contracts are those of December 2008-2012). Nord Pool offers December and March contracts for both Phases, while

[25] Additional trading days are possible in EXAA and they are announced two working days in advance.

ECX proposes contracts with monthly expiry dates from September 2006 to March 2008.

Additionally, block trades, Exchange for Physical (EFP) and Exchange for Swaps are available for ECX. The block trades allow the members to bilaterally negotiate ICE futures contracts without first revealing the order to the market so long as the order meets or exceeds a minimum volume threshold (50 contracts in the case of ICE ECX CFI futures or options). The EFP is used to mitigate the OTC risk exposures by registering the OTC positions with the ICE futures for clearing by the London Clearing House Clearnet (LCH.Clearnet). The counterparties agree that they wish to transfer an OTC position with an on-exchange futures position. The EFP position in the ECX CFI futures contract created is equivalent (in terms of volume, size and sense) to the OTC position. Note that the underlying asset in an EFP is a physical contract. The EFP is used by market participants to clear OTC forward contracts. Finally, the EFS contract works in a similar way to the EFP. The difference is that in this case the underlying asset is a financial contract. This mechanism is generally utilised to clear OTC options and swaps contracts. In Table 3, Panel B, the main characteristics of the futures markets in Europe are summarized.

Additionally, in Figure 5-C, the most representative futures prices, both for Phase I and Phase II, are presented. Again we find that Phase I price behaviour is similar to the spot and OTC Phase I prices and Phase II is analogous to the spot and OTC Phase II prices. As we can appreciate in this Figure 5-C, futures prices for Phase II behave in a similar way to futures prices for Phase I until 24th April 2006. Around this date the Phase I - Phase II prices spread started to increase. The market decided that the fundamentals of Phase I prices are not the same as of Phase II and consequently the prices evolve in a different manner. As commented before, Phase I prices decreased drastically around this date. In contrast Phase II prices decreased but did not exceed 18.5 €/tCO_2 until 3rd March 2006. Since then, Phase II futures prices moved in the range of 15-20 until 14th May 2007 when prices broke the cap and moved into the 20-25 range until the end of the sample period.

Correlation Analysis among Markets.

As we have observed in all figures of Figure 5, there is a huge similarity in the trends of Phase I OTC forward prices, spot and futures prices. The similar trend between figures can also be confirmed with a cross correlation analysis in prices (Panel A of Table 4) and returns (Panel B of Table 4).[26]

[Please, insert Table 4].

All the contemporary correlation coefficients are statistically significant at the 5% level. The positive and significant correlation coefficients indicate that all markets are strongly correlated and all of them incorporate the information in a very similar way.[27] We find the same results when comparing the spot and the Phase I future prices that continued being traded after 30th November 2005. Related to Phase II prices, the correlation is also high even if it is smaller than in the case of Phase I prices. Note that the few negative correlation coefficients in prices and returns correspond to the correlation of contracts of different Phases. The correlations of BlueNext (II) with the other markets are not statistically significant. The explanation is that we only have five prices and four returns of BlueNext (II) and thus, the results are not representative.

[26] The returns have been defined as $r_t=ln(P_t/P_{t-1})$, where P_t is the price series at time t.

[27] As trading in the EXAA market only takes place once a week, it has been eliminated from the correlations of prices and returns as the number of observations is very small. Climex Aliance and GME have also not been included since not enough data is available.

Volume Analysis.

In terms of volume, measured in tonnes of CO_2, the most important market of spot contracts is BlueNext (73%) and the most important market for future contracts is ECX (96%). Figure 6 shows the total volume of the EU ETS and the volumes of futures and spot markets.

[Please, insert Figure 6].

Additionally, as we can appreciate in Figure 6, the volume of EUAs traded with futures contracts is much higher than those traded in the spot market. Moreover, the Phase II contract has become the most traded one, representing 70% of the total futures traded. Note that the OTC volume considered in this picture represents only the trades done through the LEBA members.

Options Trading.

In addition to spot and futures contracts, since 13th October 2006, it has also been possible to trade options on EUAs futures in the ECX. The trading is done from Monday to Friday, the delivery is physical and the minimum contract size is 1000 tCO_2. There are 55 strike prices automatically listed for each contract month covering the price range from €1 to €55. The contract months are the last contract of each quarter (March, June, September, and December) from 2008 to 2012. Additionally, the Exchange may add one or more strike prices nearest to the last price listed as necessary. Note that the strike price intervals are €1. The options are exercised into ICE Futures ECX CFI EUAs futures contracts and are European-style exercise. In Table 3, Panel C, the main characteristics of the options trading in ECX are summarized.

1.5. LINKING WITH UNITED NATIONS CARBON MARKETS

As we have seen in the previous sections, following the ratification of the Kyoto Protocol, it is possible for European countries to use, together with the EUAs, the CERs and the ERUs to comply with its emission reductions obligations for Phase I or Phase II of the EU ETS.[28] Following the linking Directive (2004/101/EC), in order to use those units, the Member States have to give their permission through the NAPs. If permission is given, the Member States will also have to set a limit on how many CERs and EURs can be surrendered as a percentage of allocation, or in global terms at installation or at the national level. In Table 2 the limit allowed for each European Member State is presented in terms of percentage of total emissions for 2008-2012.

The units CERs and ERUs may be obtained both by the realization of the project for emissions reductions (JI and CDM, respectively), or through the secondary market. The importance of the agents that participate in the elaboration of projects via CDM or JI is increasing as they are potential sellers of CERs and ERUs, respectively.

As in the case of the EUAs, it is possible to trade CERs via OTC trades or in organized markets. There are no OTC indexes, as in the case of EUAs, that reflect CERs and ERUs OTC forward prices, and, consequently, it is not possible to reflect the behavior of those prices. Nevertheless, it is also possible to trade CERs in organized markets. Nord Pool has offered future contracts on CERs since June 2007, and ECX since 14th March 2008. Figure 7 presents the evolution of the CERs futures prices at Nord Pool.

[Please, insert Figure 7].

[28] Note that although there was the possibility to use the Kyoto project based mechanisms for compliance of Phase I objectives, it was not economically interesting due principally to the low EUAs prices at the end of Phase I.

As we can appreciate in Figure 7, the evolution of the different CERs futures contracts in Nord Pool has been quite similar. In addition, they behave in a similar manner to the December 2008 EUAs future contract traded at ECX.[29] However, note that even if EUAs are exchangeable with CERs and ERUs in terms of compliance, and we might think they are a perfect substitution, there are important differences between EUAs and the units issued from projects. First of all, there is a source of uncertainty related to the units the project will lead to. Secondly, the percentage of units each country will allow to use in order to achieve the Kyoto target as a percentage of the total units assigned will not be made public until all Phase II NAPs have been accepted by the European Commission. Finally, it will not be possible to transfer these types of units until the ITL is working perfectly and all countries are linked to it through the United Nations framework. All those reasons explain why the CERs futures prices at Nord Pool are some euros cheaper than the EUAs traded at ECX. While EUAs have been traded since June 2007 in a range of €18 to €24, the CERs have been negotiated in a range of €14 to €19. However, all those risks are becoming less uncertain and we should expect that in order to avoid arbitrage opportunities, the difference should start to narrow.

The market of CERs is in an expansion period but the volumes in organized trading are still small (see Figure 7). In addition to the possibility to negotiate in Nord Pool and ECX futures contracts for CERs, Bluenext will launch in the near future spot and futures trading of CERs issued by the Executive Committee of CDM Board for projects selected on the advice of BlueNext's Expert Committee, and ECX will launch an option contract on CERs. Additionally, from 26th March 2008, it will be possible to trade

[29] This is also supported by a correlation analysis among those variables. The correlations both in prices and returns are statistically significant and positive. In all cases they are higher than 50%.

futures on CERs on the Eurex/EEX.[30] In Table 5 the characteristics of each of those contracts are presented. In Panel A (B), we present the trading rules for the spot (futures) contracts. In Panel C the trading rules for options contracts are shown.

[Please, insert Table 5].

There are several expiry dates for the CERs futures contracts that vary among markets (see Panel B in Table 5). In the case of Nord Pool, there are December and March futures contract from December 2005 until December 2012, in the case of ECX, the expiry of the contracts is in the last month of each quarter (March, June, September, and December), and in the case of BlueNext, it is only possible to trade December futures contracts from 2008 to 2012. In all cases the contracts are daily traded, the trade is done in lots of 1000 CERs, and the minimum tick is €0.01.

The main characteristics of the option contract that will be traded in the near future in ECX are presented in Table 5, Panel C. The trade is also daily, it is done in lots of 1000 CERs, and the minimum tick is €0.01. The options are exercised into ICE Futures ECX CFI CERs futures contracts and have European-style exercise. Additionally, 55 strike prices are automatically listed for each contract (there are contracts for each of the final months of the quarter) covering the price range from €1 to €55 (note that the strike price intervals are €1). Finally, the exchange may add one or more strike prices nearest to the last price listed if necessary.

Other than in Europe it is also possible to trade EUAs and CERs. The Green Exchange has offered, since 17th March 2008, the possibility to trade futures on EUAs and CERs, and options on EUAs futures. Both the EUAs futures contract and CERs futures

30 See http://www.eurexchange.com/about/press/press_556_en.html for more information on CERs trading at EEX.

contract are physically delivered at the UK Emissions Trading Registry. The contract size is 1000 metric tonnes of CO_2 and the minimum price fluctuation is €0.01 per unit. In the case of the EUAs options contract, they are European-style options that will exercise into the underlying EUAs futures contract. It will expire three business days prior to the EUAs futures contract and will have 10 strike prices in increments of €0.50 above and below the at-the-money strike price. The EUAs options will be traded on the NYMEX trading floor and cleared on NYMEX ClearPort. Finally, the Chicago Climate Exchange has organized an auction of CERs that have been issued by the UNFCCC from a wind energy farm project in India. Additionally, the Multi Commodity Exchange of India has recently launched contracts on carbon credits.

It is important to emphasize that no Kyoto transaction can take place without the ITL as no European Union transaction can take place without the CITL. That means that a CER cannot be formally issued or forwarded to a registry without the ITL. For this reason, CERs trades started to be done through futures or forward contracts were subject to the effective link between European registers and the ITL. The trading of the Kyoto Protocol CERs and ERUs was done at a discount due to the possibility that the ITL did not become operational before the end of the Phase I of the EU ETS.

In addition to the units issued from the different type of projects, it is also possible, under the Kyoto Protocol emissions trading flexibility mechanism, to trade the emissions permits from other emissions trading schemes. In addition to the European Union, as we have seen, launching the European Union Emission Trading Scheme, other countries have also launched their own emission trading schemes. For example, the USA has launched the Regional Greenhouse Gas Initiative (the first RGGI trade was announced on 15th February 2008), Japan also has its pilot project emission trading scheme, and this is also the case for South Korea, New Zealand, Switzerland, and Australia.[31] Norway also has an Emission Trading Scheme that is the most comparable to the EU ETS, and Canada and the European Union have agreed to make their CO_2 emissions trading schemes compatible. The objective is that all those schemes will be linked to the ITL in order to have a global CO_2 market.

However, it is not easy to link the different systems adopted by all those countries. First of all, the systems have, in most cases, characteristics that are not comparable and secondly, in order to completely link the different markets it is compulsory that each partner accept the allowances issued by any program linked. Even if it is not easy, efforts are being made in this direction. A significant example is that the European Commission has agreed with countries in the European Economic Area (Norway, Iceland and Liechtenstein) on linking their respective emissions trading schemes, making the first international link between emissions trading schemes. See Kruger et al. (2007) for a discussion of linking issues.

Almost all parties have now completed the initialization of their registry connections with the ITL. This process verifies that they meet all technical requirements prior to the beginning of the operations with the ITL. Only Japan, New Zealand and Switzerland have completed their initialization process.[32]

1.6. SUMMARY AND CONCLUDING REMARKS

In this chapter we have studied several aspects of CO_2 trading worldwide. First, we have presented the Kyoto Protocol. We have analysed the state of commitment of the

[31] For further information on the first RGGI trade, see Point Carbon (15th February 2008).
[32] See http://unfccc.int/kyoto_protocol/registry_systems/itl/items/4065.php for further information on the International Transaction Log,

different countries that have signed the Kyoto Protocol and we have presented the flexibility mechanisms that allow for easier compliance. Among those flexibility mechanisms we find emissions trading, the principal subject of this chapter.

Even if there have been many experiences with emissions trading, in this chapter we focus on the EU ETS. The elaboration of the National Allocation Plans procedure, the distribution among European countries of the allowances, and the verification of real emissions obligations, etc… are explained in detail. Following this, we have presented the existing spot, forward, futures and options markets of EUAs. In terms of prices we have illustrated that Phase I prices, independently of the market where they are negotiated, follow the same evolution and are on the same levels. This is also the case for Phase II prices.

The linking possibilities of the EU ETS with the United Nation carbon markets are also analysed in this chapter. We emphasize the importance of the ITL and the role of the developing and economies-in-transition countries on mitigating the impact of climate change through the elaboration of reduction emissions projects that lead to CERs and ERUs, respectively.

Finally, we would like to underline that there are a wide variety of participants in the carbon markets. We firstly find the industrial agents that are directly concerned with CO_2 emissions reductions, secondly the brokers and, finally, the financial institutions. Additionally, the importance of the agents that participate in the elaboration of the projects via CDM and JI is increasing as they are potential sellers of CERs and ERUs.

As a global conclusion to this chapter, we want to highlight some aspects: (i) the EU ETS has succeeded in imposing a price on carbon emissions, which was one of its most important objectives, (ii) trading in CO_2 spot, forward and futures markets is increasing at high rates, (iii) options contracts have been recently listed and the creation of these types of contracts in organized markets is considered by traders as a sign that the futures market is mature enough and will contribute to creating more liquidity in the futures markets, (iv) the secondary market of CERs is the segment with the highest development and, following the present estimations, it will contribute to creating an equilibrium between the offer and the demand in the carbon markets.

Table 1: Annex B Countries Emission Targets.

This Table shows the emissions percentage target of the Annex B countries of the Kyoto Protocol. The percentage represents the effort of emission reduction that countries must do in the period 2008-2012 taking as reference the year 1990. As we can see, there are some positive percentages. This means that the country is authorised to increase its actual CO_2 emissions from those in 1990 (i.e. this is the case of Norway, Australia and Spain) while other countries must reduce them (i.e. the US, Germany or Denmark). *Source: Kyoto Protocol and United Nations: FCCC/CP/2004/5 and the Burden Sharing Agreement*.

Country	Target
Iceland	10%
US	- 7%
Canada, Hungary, Japan, Poland	- 6%
Croatia	- 5%
New Zealand, Russian Federation, Ukraine	0%
Norway	1%
Australia	8%
Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland,	- 8%
Total European Union	-8%
Germany	- 21%
Austria	- 13%
Belgium	- 8%
Denmark	- 21%
Spain	15%
France, Finland	0%
Greece	25%
The Netherlands	- 6%
Ireland	13%
Italy	- 6.5%
Luxembourg	- 28%
Portugal	27%
United Kingdom	- 12.5%
Sweden	4%

Table 2: Final Commission decision on NAPs.

This table presents the European Commission decision on NAPs for all countries of the European Union. In the first column we find the Member States. The cap for the Phase I is shown in the second column. The verified emissions for the year 2005 are presented in the third column. The fourth column presents the proposed cap for Phase II by countries. The fifth column presents the cap finally allowed by the European Commission; in brackets we find the percentage allowed in relation to the emissions proposed. In the sixth column the emissions from additional installations in 2008-2012 are presented, and in the last column the JI/CDM limit for Phase II of the EU ETS I shown. *Source: European Commission.*

Member State	1st period cap (2005-2007)	2005 verified emissions	Proposed cap 2008-2012	Cap allowed 2008-2012 (in relation to proposed)		Emissions from additional installations in 2008-2012[1]	JI/CDM limit 2008-2012 in %[2]
Austria	33.0	33.4	32.8	30.7	(93.6%)	0.35	10
Belgium	62.1	55.58[3]	63.3	58.5	(92.4%)	5.0	8.4
Bulgaria	42.3	40.6[4]	67.6	42.3	(62.6%)	n.a[5]	12.55
Cyprus	5.7	5.1	7.12	5.48	(77%)	n.a.	10
Czech Rep.	97.6	82.5	101.9	86.8	(85.2%)	n.a.	10
Denmark	33.5	26.5	24.5	24.5	(100%)	0	17.01
Estonia	19	12.62	24.38	12.72	(52.2%)	0.31	0
Finland	45.5	33.1	39.6	37.6	(94.8%)	0.4	10
France	156.5	131.3	132.8	132.8	(100%)	5.1	13.5
Germany	499	474	482	453.1	(94%)	11.0	20[6]
Greece	74.4	71.3	75.5	69.1	(91.5%)	n.a.	9
Hungary	31.3	26.0	30.7	26.9	(87.6%)	1.43	10
Ireland	22.3	22.4	22.6	22.3	(98.6%)	n.a.	10
Italy	223.1	225.5	209	195.8	(93.7%)	n.k. [7]	14.99
Latvia	4.6	2.9	7.7	3.43	(44.5%)	n.a.	10
Lithuania	12.3	6.6	16.6	8.8	(53%)	0.05	20
Luxembourg	3.4	2.6	3.95	2.5	(63%)	n.a.	10
Malta	2.9	1.98	2.96	2.1	(71%)	n.a.	n.a.
Netherlands	95.3	80.35	90.4	85.8	(94.9%)	4.0	10
Poland	239.1	203.1	284.6	208.5	(73.3%)	6.3	10
Portugal	38.9	36.4	35.9	34.8	(96.9%)	0.77	10
Romania	74.8	70.8[8]	95.7	75.9	(79.3%)	n.a	10
Slovakia	30.5	25.2	41.3	32.6	(78.9%)	1.78	7
Slovenia	8.8	8.7	8.3	8.3	(100%)	n.a.	15.76
Spain	174.4	182.9	152.7	152.3	(99.7%)	6.7[9]	20
Sweden	22.9	19.3	25.2	22.8	(90.5%)	2.0	10
UK	245.3	242.4[10]	246.2	246.2	(100%)	9.5	8
SUM	**2298.5**	**2122.16[11]**	**2325.34**	**2082.68**	**(89.56%)**	**54.69**	-

All figures are annual, in million tonnes of CO_2.
[1] The figures indicated in this column comprise emissions in installations that come under the coverage of the scheme in 2008 to 2012 due to an extended scope applied by the Member State and do not include new installations entering the scheme in sectors already covered in the first trading period.
[2] The JI/CDM limit is expressed as a percentage of the member state's cap and indicates the maximum extent to which companies may surrender JI or CDM credits instead of EU ETS allowances to cover their emissions. These credits are generated by emission-saving projects carried out in third countries under the Kyoto Protocol's project-based flexible mechanisms, known as Joint Implementation (JI) and the Clean Development Mechanism (CDM).
[3] Including installations which Belgium opted to exclude temporarily from the scheme in 2005
[4] Due to Bulgaria's recent accession to the EU, this figure is not independently verified.
[5] n.a. means data not available.
[6] The German national allocation law contains a figure of 22 %, which relates to the allowances allocated free of charge, rather than the total cap.
[7] Italy has to include further installations. The amount of additional emissions is not known at this stage.
[8 Due to Romania's recent accession to the EU, this figure is not independently verified.
[9] Additional installations and emissions of over 6 million tonnes are already included as of 2006.
[10] Verified emissions for 2005 do not include installations which the UK opted to exclude temporarily from the scheme in 2005 but which will be covered in 2008 to 2012 and are estimated to amount to some 30 Mt.
[11] The sum of verified emissions for 2005 does not include installations which the UK opted to exclude temporarily from the scheme in 2005 but which will be covered in 2008 to 2012 and are estimated to amount to some 30 Mt. Furthermore, the emissions figures for Bulgaria and Romania are not independently verified.

Table 3: EUAs Trading Rules Details in Organized Markets.

Panel A presents the main characteristics of the EUAs spot markets. For all of them, some characteristics are shown: the commodity, the country, the date where they were launched, the trading days, the delivery, the unities of the contracts, the minimum contract size, the minimum tick, the registry name of the country and the authority that manages the registry. Note that BlueNext has already launched spot trading for Phase II EUAs and Nord Pool will launch them 15th April 2008. Spot trading in Nord Pool for Phase I EUAs will last until 31st March 2008. Spot contracts for Phase II will have the same trading rules. Panel B shows the same information for the futures contracts. Additionally the expiry of the contract is shown. Panel C shows the same information for Options trading. *Source: Own elaboration from markets web pages.*

Panel A: Spot Trading Rules Details in Organized Markets for Phase I EUAs.

	BlueNext	**Energy Exchange of Austria (EXAA)**	**Nord Pool**	**Gestore Mercato Elettrico (GME)**	**European Energy Exchange (EEX)**
Commodity	EUA	EUA	EUA	EUA	EUA
Country	France	Austria	Scandinavia	Italy	Germany
Market Launch	24th April 2005	28th June 2005	24th October 2005	2nd April 2007	9th March 2005
Trading Days	From Monday to Friday	Weekly trading	From Monday to Friday	From Monday to Friday	From Monday to Friday
Delivery	Physical	Physical	Physical	Physical	Physical
Unity	1 EUA	1 EUA	1 EUA	1 EUA	1 EUA
Minimum contract size	1000 tCO2	1 tCO2	1000 tCO2	500 tCO2	1 tCO2
Tick minimum	€0.01	€0.01	€0.01	€0.01	€0.01
Registry	Seringas	ECRA (Emission Certificate Registry Austria)	NEA (Dutch Emission Authority)	Sina Group	DEHSt (German Emissions Trading Authority)
Registry Management	Caisse des dépôts et consignations	ECRA (Emission Certificate Registry Austria)	Dutch Emission Authority	APART (Italian Environmental Authority)	DEHSt (German Emissions Trading Authority)
Clearing	LCH Clearnet SA	APCS (Austrian Power Clearing and Settlement AG)	Nord Pool Clearing ASA	Gestore Mercato Elettrico (GME) S.p.a.	Several Banks

Panel B: Futures Trading Rules Details in Organized Markets.

	Nord Pool	**European Climate Exchange (ECX)**	**European Energy Exchange (EEX) / Eurex**	**BlueNext**	**The Green Exchange**
Commodity	EUA	EUA	EUA	EUA	EUA
Country	Scandinavia	United Kingdom	Germany	France	USA
Market Launch	11th February 2005	22nd April 2005	4th October 2005	*In the near future*	17th March 2008
Trading Days	From Monday to Friday	From Monday to Friday	From Monday to Friday	From Monday to Friday	From 6:00 pm Sundays through 5:15 pm Fridays, Eastern Time
Contract Expiry	December 2005. December and March from 2006 to 2012	Quarterly contracts for 2005 and 2006. From September 2006 to March 2008 monthly contracts. December contracts from 2008 to 2012.	December contracts from 2006 to 2012	December contracts from 2008 to 2012	Quarterly contracts from December 2008 to December 2010 December contracts from 2011 to 2012
Delivery	Physical	Physical	Physical	Physical	Physical
Unity	1 EUA	1 EUA	1 EUA	1 EUA	1 EUA
Minimum contract size	1000 tCO2	1000 tCO2	1000 tCO2	1000 tCO2	1000 tCO2
Tick minimum	€0.01	€0.01	€0.01	€0.01	€0.01
Registry	Nea (Dutch Emission Authority)	Environment Agency	DEHSt (German Emissions Trading Authority)	Seringas	UK Emissions Trading Registry
Registry Management	Dutch Emission Authority	Environment Agency	DEHSt (German Emissions Trading Authority)	Caisse des dépôts et consignations	Environment Agency
Clearing	Nord Pool Clearing ASA	London Clearing House (LCH.Clearnet)	Eurex Clearing AG and the European Commodity Clearing AG (ECC).	LCH Clearnet SA	NYMEX ClearPort

Table 3: EUAs Trading Rules Details in Organized Markets (continued).

Panel C shows the same information for Options trading. Including the type of commodity, the country of the market, the launch date, the trading days, the different contract expiry possibilities, the delivery, the unity, the minimum contract size, the strike price increments, the minimum tick, the option premium, the nature of exercise of the option, the registry, the registry management and the clearing house. *Source: Own elaboration from markets web pages.*

Panel C: Options Trading Rules Details in Organized Markets.

	European Climate Exchange (ECX)	The Green Exchange
Commodity	EUA	EUA
Country	United Kingdom	USA
Market Launch	13th October 2006	17th March 2008
Trading Days	From Monday to Friday	From 6:00 pm Sundays through 5:15 pm Fridays, Eastern Time
Contract Expiry	Front two contracts plus next six December contract months. Currently Jan08, Feb08, December contracts from 2008-2012 are listed.	Quarterly contracts from December from 2008 to December 2010 December contracts from 2011 to 2012
Delivery	Physical	Physical
Underlying	Exercised into ICE Futures ECX CFI EUAs futures contracts.	1 EUAs futures contract
Minimum contract size	1000 tCO2	1000 tCO2
Strike price increments	Fifty-five strike prices are automatically listed for each contract month covering the price range from €1- €55. The Exchange may add one or more strike prices nearest to the last price listed as necessary. Strike price intervals are €1.	10 strike prices in increments of €0.50 above and below the at-the-money strike price.
Tick minimum	€0.01	€0.01
Option Premium	Premiums are paid at the time of the transaction	Premiums are paid at the time of the transaction
Nature of exercise	European-style exercise	European-style exercise
Registry	Environment Agency	UK Emissions Trading Registry or at the Dutch CO_2 Emissions Trading Registry
Registry Management	Environment Agency	Environment Agency Dutch Emission Authority
Clearing	London Clearing House (LCH.Clearnet)	NYMEX ClearPort

Table 4: Cross correlation analysis between European markets.

This Table presents the cross correlation analysis between the different European markets. Panel A (B) presents the correlation in Prices (Returns). EEX is the spot prices (returns) traded in EEX, BlueNext I (II) refers to spot trading in BlueNext for Phase I (II), Nord Pool refers to spot prices (returns) traded at Nord Pool, Carbon Index is the Carbon Index calculated by EEX, LEBA I (II) refers to OTC trading in LEBA for Phase I (II), EEX 2007 (2008) refers to the futures contract with delivery December 2007 (2008) traded in EEX, Nord Pool 2007 (2008) is the futures contract with delivery December 2007 (2008) traded in Nord Pool, and ECX 2007 (2008) is the futures contract with delivery December 2007 (2008) traded in ECX. All the correlation coefficients are statistically significant at 5% level except those in italics. n.a. is used when the series do not coincide and thus the correlations can not be calculated.

Panel A: Prices Correlation

	EEX	Bluenext (I)	Bluenext (II)	NordPool	Carbon Index	LEBA (I)	LEBA (II)	EEX 2007	EEX 2008	NordPool 2007	NordPool 2008	ECX 2007	ECX 2008
EEX	1.00000												
Bluenext (I)	0.99980	1.00000											
Bluenext (II)	-0.20270	n.a.	1.00000										
NordPool	0.99981	0.99989	n.a.	1.00000									
Carbon Index	0.99705	0.99136	n.a.	0.96299	1.00000								
LEBA (I)	0.99954	0.99964	n.a.	0.99975	0.99783	1.00000							
LEBA (II)	-0.47814	-0.47885	0.36750	-0.47754	n.a.	-0.42615	1.00000						
EEX 2007	0.99939	0.99946	n.a.	0.99959	0.97008	0.99965	-0.43819	1.00000					
EEX 2008	0.35420	0.35335	n.a.	0.33743	0.83095	0.46705	0.99633	0.43456	1.00000				
NordPool 2007	0.99905	0.99932	n.a.	0.99958	0.99774	0.99954	-0.44264	0.99995	0.42384	1.00000			
NordPool 2008	0.34385	0.34027	0.42720	0.34319	n.a.	0.46638	0.99589	0.43464	0.99792	0.42818	1.00000		
ECX 2007	0.99916	0.99912	n.a.	0.99933	0.98883	0.99940	-0.45356	0.99974	0.40570	0.99969	0.40306	1.00000	
ECX 2008	0.39812	0.41415	-0.44793	0.31809	0.92006	0.50564	0.99428	0.43025	0.99668	0.46820	0.99553	0.45194	1.00000

Panel B: Returns Correlations

	EEX	Bluenext (I)	Bluenext (II)	NordPool	Carbon Index	LEBA (I)	LEBA (II)	EEX 2007	EEX 2008	NordPool 2007	NordPool 2008	ECX 2007	ECX 2008
EEX	1.00000												
Bluenext (I)	0.42534	1.00000											
Bluenext (II)	*-0.20327*	n.a.	1.00000										
NordPool	0.40474	0.58699	n.a.	1.00000									
Carbon Index	0.78313	0.71736	n.a.	0.61560	1.00000								
LEBA (I)	0.49908	0.69480	n.a.	0.65118	0.89882	1.00000							
LEBA (II)	0.01974	0.08847	*-0.43407*	0.17378	n.a.	0.19997	1.00000						
EEX 2007	0.72562	0.70322	n.a.	0.66128	0.63234	0.71979	0.24132	1.00000					
EEX 2008	0.25502	0.33562	n.a.	0.34647	0.36285	0.36027	0.80287	0.50671	1.00000				
NordPool 2007	0.58644	0.59985	n.a.	0.78072	0.79901	0.66657	0.17962	0.72799	0.38210	1.00000			
NordPool 2008	0.23438	0.32574	*0.14955*	0.34560	n.a.	0.37068	0.81967	0.49925	0.93002	0.38465	1.00000		
ECX 2007	0.06385	0.15152	n.a.	0.30934	0.68800	0.39319	0.16582	0.73877	0.28360	0.34624	0.27196	1.00000	
ECX 2008	0.22916	0.28650	-0.88829	0.29816	0.61754	0.32671	0.65726	0.43492	0.84116	0.33872	0.78855	0.32829	1.00000

Table 5: CERs Trading Rules Details in Organized Markets.

This picture shows the trading rules details in organized markets for the different CERs contracts. Panel A presents the CERs spot trading rules details, Panel B the CERs futures trading rules details and Panel C the CERs Options trading rules details. The commodity, the country, the market launch, the trading days, the delivery, the unity, the minimum contract size, the tick minimum, the registry, the registry management and the clearing are shown. *Source: Own elaboration from markets web pages.*

Panel A: CERs Spot Trading Rules Details in Organized Markets

	BlueNext
Commodity	CER
Country	France
Market Launch	*In the near future*
Trading Days	From Monday to Friday
Delivery	Physical
Unity	1 CER
Minimum contract size	1000 tCO2
Tick minimum	€0.01
Registry	Seringas
Registry Management	Caisse des dépôts et consignations
Clearing	LCH Clearnet SA

Panel B: CERs Futures Trading Rules Details in Organized Markets.

	Nord Pool	**European Climate Exchange (ECX)**	**BlueNext**	**The Green Exchange**
Commodity	CER	CER	CER	CER
Country	Scandinavia	United Kingdom	France	USA
Market Launch	1st June 2007	14th March 2008	*In the near future*	17th March 2008
Trading Days	From Monday to Friday	From Monday to Friday	From Monday to Friday	From 6:00 pm Sundays through 5:15 pm Fridays, Eastern Time
Contract Expiry	December contracts from 2006 to 2012	Quarterly contracts from December 2008 to December 2012.	December contracts from 2008 to 2012	Quarterly contracts from December 2008 to December 2010 December contracts from 2011 to 2012
Delivery	Physical	Physical	Physical	Physical
Unity	1 CER	1 CER	1 CER	1 CER
Minimum contract size	1000 tCO2	1000 tCO2	1000 tCO2	1000 tCO2
Tick minimum	€0.01	€0.01	€0.01	€0.01
Registry	NEA (Dutch Emission Authority)	Environment Agency	Seringas	UK Emissions Trading Registry or at the Dutch CO2 Emissions Trading Registry
Registry Management	Dutch Emission Authority	Environment Agency	Caisse des dépôts et consignations	Environment Agency Dutch Emission Authority
Clearing	Nord Pool Clearing ASA	London Clearing House (LCH.Clearnet)	LCH Clearnet SA	NYMEX ClearPort

Table 5: CERs Trading Rules Details in Organized Markets (continued).

Panel C of this picture shows the CERs Options futures trading rules details. As in the other two panels, the type of commodity, the country of the market, the launch date, the trading days, the different contract expiry possibilities, the delivery, the unity, the minimum contract size, the strike price increments, the minimum tick, the option premium, the nature of exercise of the option, the registry, the registry management and the clearing house. *Source: Own elaboration from markets web pages.*

	European Climate Exchange (ECX)
Commodity	CER
Country	United Kingdom
Market Launch	*In the near future*
Trading Days	From Monday to Friday
Contract Expiry	Quarterly contracts from December 2008 to December 2012.
Delivery	Physical
Unity	Exercised into ICE Futures ECX CFI CER futures contracts.
Minimum contract size	1000 tCO2
Strike price increments	Fifty-five strike prices are automatically listed for each contract month covering the price range from €1 to €55. The Exchange may add one or more strike prices nearest to the last price listed as necessary. Strike price intervals are €1.00.
Tick minimum	€0.01
Option Premium	Premiums are paid at the time of the transaction
Nature of exercise	European-style exercise
Registry	Environment Agency
Registry Management	Environment Agency
Clearing	London Clearing House (LCH.Clearnet)

Figure 1: Kyoto Protocol Flexibility Mechanisms.

This Figure shows schematically the relationship between the EU ETS and the Kyoto Protocol flexibility mechanisms. CDM is the Clean Development Mechanism, JI is the Joint Implementation Mechanism, EU ETS is the European Union Emission Trading Scheme, EUAs are the European Union Allowances, ERUs are the Emission Reduction Units, CERs are the Certificate Emission Reductions, CITL is the Community Independent Transaction Log, and ITL is the International Transaction Log. Note that the ITL has been operational from November 2007. In the squares with small dots we find the European Companies and Member States compliance possibilities. *Source: Own elaboration.*

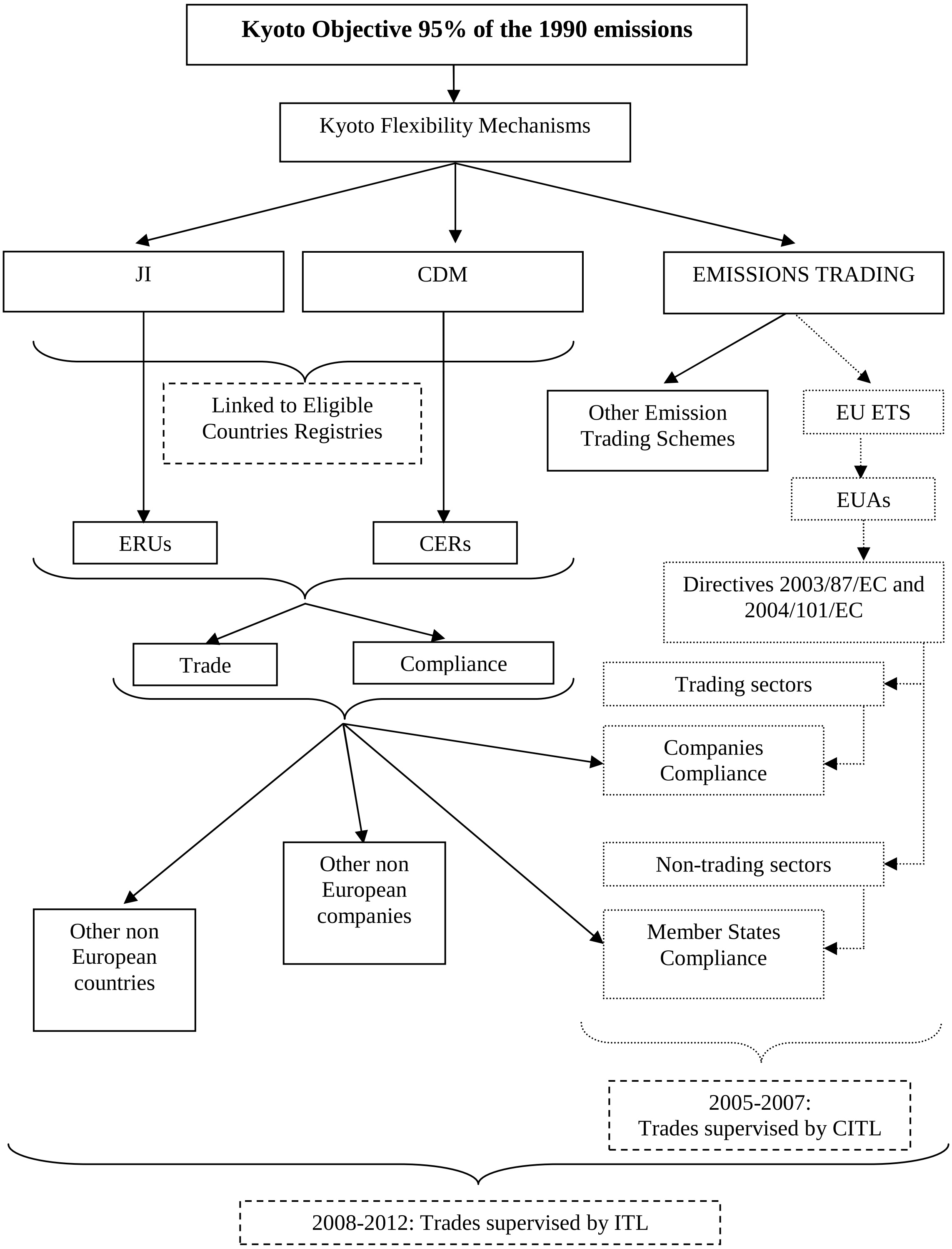


Figure 2: Annex B CO_2-e emissions for the period 1990-2005.

Figure 2-A shows Annex B countries' Kyoto target, real emissions change in 1990-2005 without Land-Use, Land-Use Change and Forestry (LULUCF), and the excess of emissions from its targets. Figure 2-B shows the same variables for European Countries. The base year is in all cases 1990 except for Bulgaria and Poland, whose base year is 1988, for Hungary, whose base year is the average of the years between 1985 and 1987, for Romania, whose base year is 1987, and for Slovenia whose base year is 1986. *Source: United Nations Framework on Climate Change and EEA.*

Figure 2-A: Annex B Countries Verified Emissions 2004

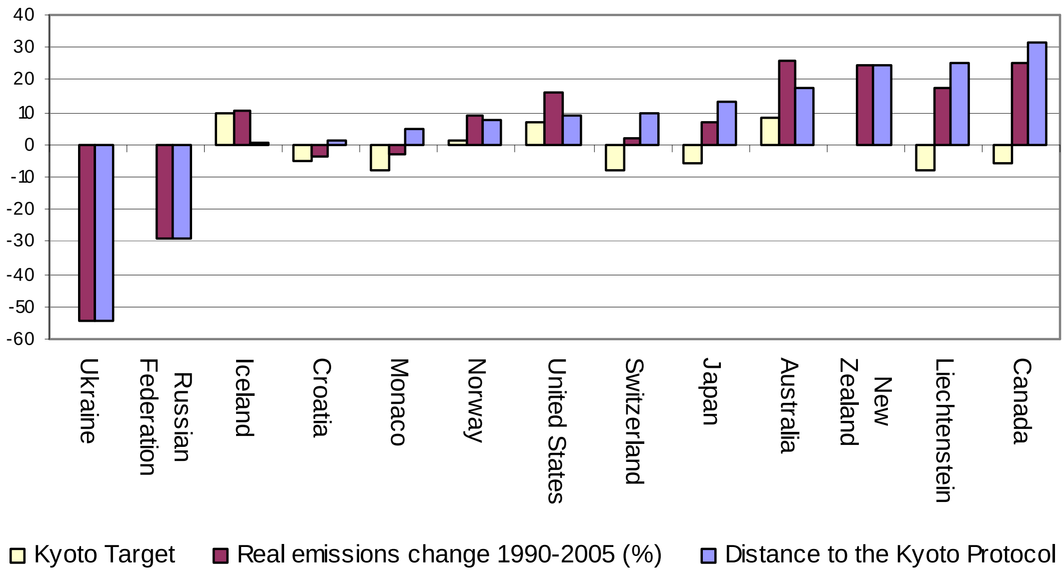


Figure 2-B: European Countries Verified Emissions 2005

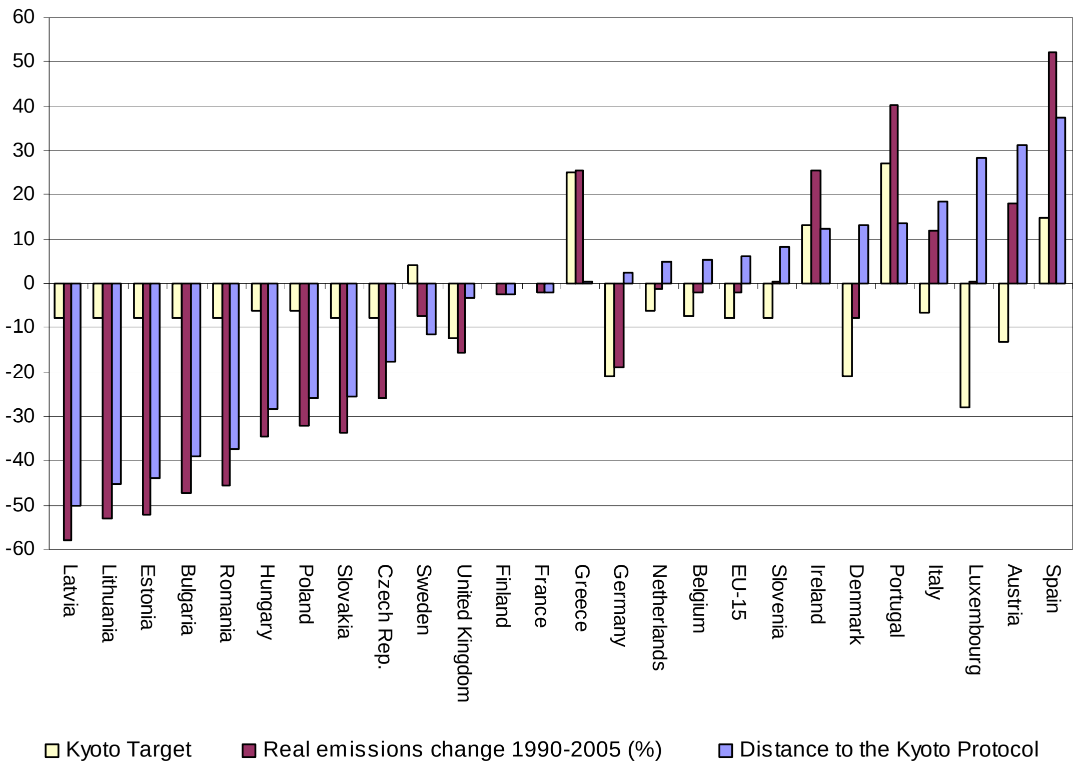


Figure 3: Percentages of the Allocations of Large European Countries.

In Figure 3-A (B) the percentage of total allowances distributed in Europe for Phase I (II) is presented. Only the countries representing more than 5% of total emissions are considered. The countries that represent less than 5% are grouped in *Others*. *Source: European Commission.*

Figure 3-A: Percentages of Total Allowances Distribution by Countries for Phase I

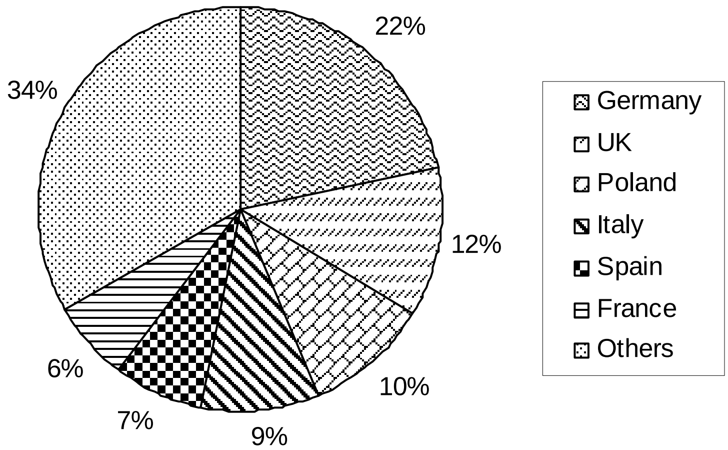


Figure 3-B: Percentages of Total Allowances Distribution by Countries for Phase II

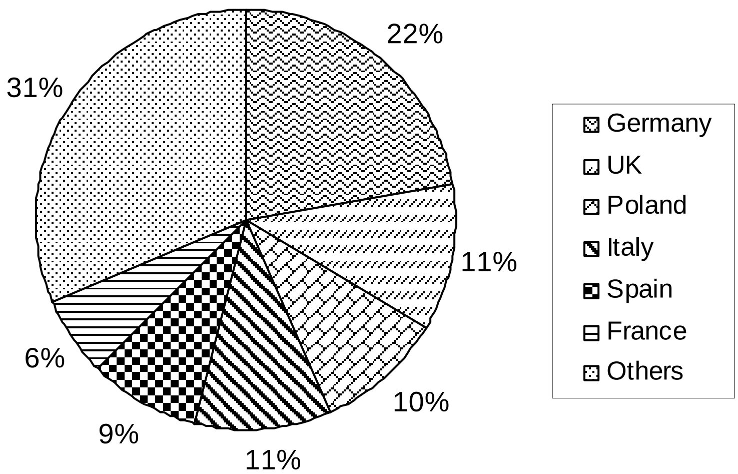


Figure 4: Deadlines of the EU ETS.

This Figure shows how the deadlines are organised in the EU ETS. First of all, the real emissions take place, then a verified report has to be presented by each Member State to the European Commission before 31st March of the following year and before 30th April the companies should surrender the allowances that correspond to their real emissions. In the case they do not have enough allowances, they must pay a penalty but that does not release them from the responsibility of presenting the allowances. *Source: Own elaboration from 2003/87/EC Directive.*

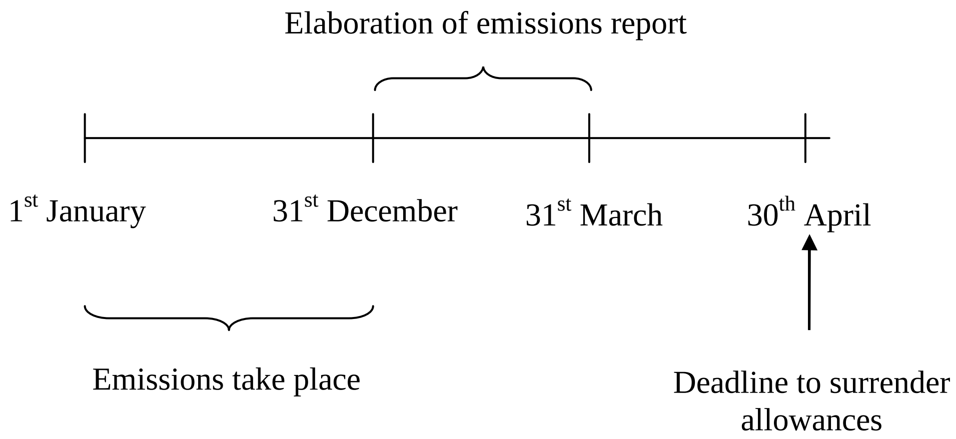


Figure 5: Trends of Carbon Prices.

These Figures show the trends of the most relevant carbon prices in Europe. In Figure 5-A the OTC forward indices are shown, in Figure 5-B the spot prices are exhibited and in Figure 5-C the futures prices are presented. EEX refers to the carbon index traded in European Energy Exchange, LEBA (I) and BlueNext (I) refer to Phase I prices and LEBA (II) and BlueNext (II) to Phase II prices. The futures contract corresponds to the December contract of the year indicated. *Source: Markets web pages.*

Figure 5-A: Trends of OTC Carbon Prices

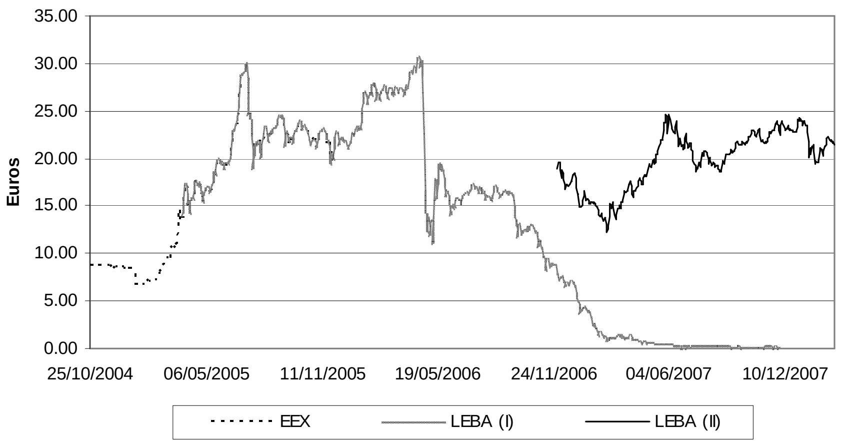


Figure 5-B: Trends of Spot Carbon Prices

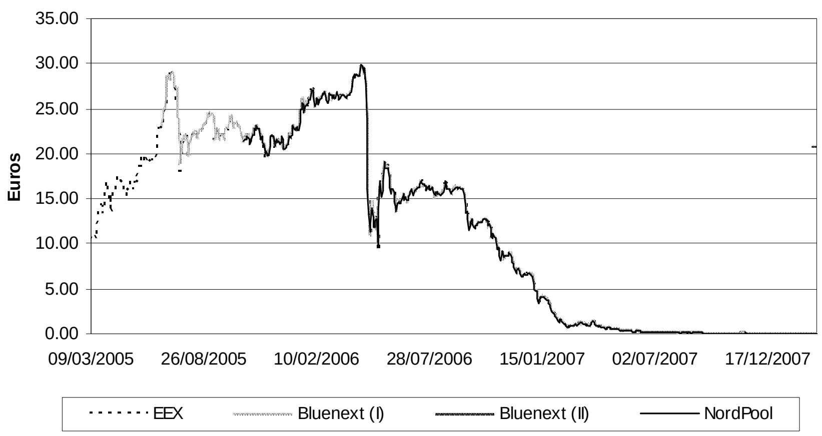


Figure 5-C: Trends of Futures Carbon Prices

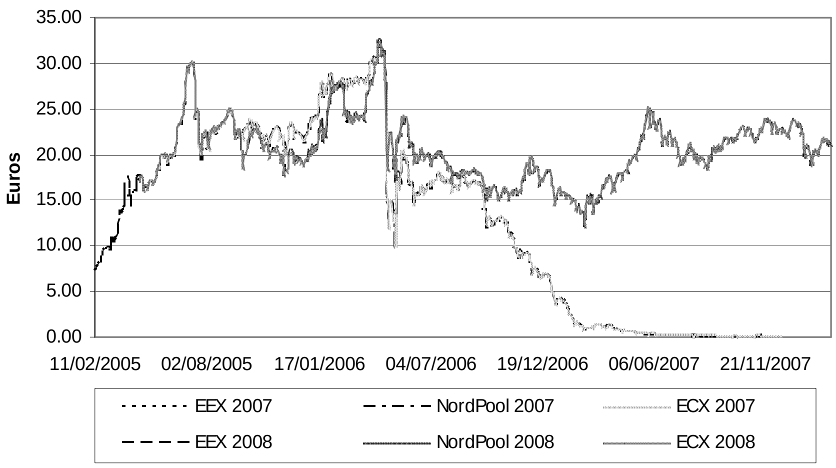


Figure 6: Traded Volume in EU ETS.

This Figure shows volumes traded in the EU ETS. In the first picture we distinguish between spot, futures and OTC trading, and then we focus on the spot and futures markets. The spot and futures markets by phases and by markets are presented. All volumes are cumulated volumes from the first trade in each market to the end of the trading of the contract. The volumes are expressed in tonnes of CO_2. *Source: Own elaboration from market web pages.*

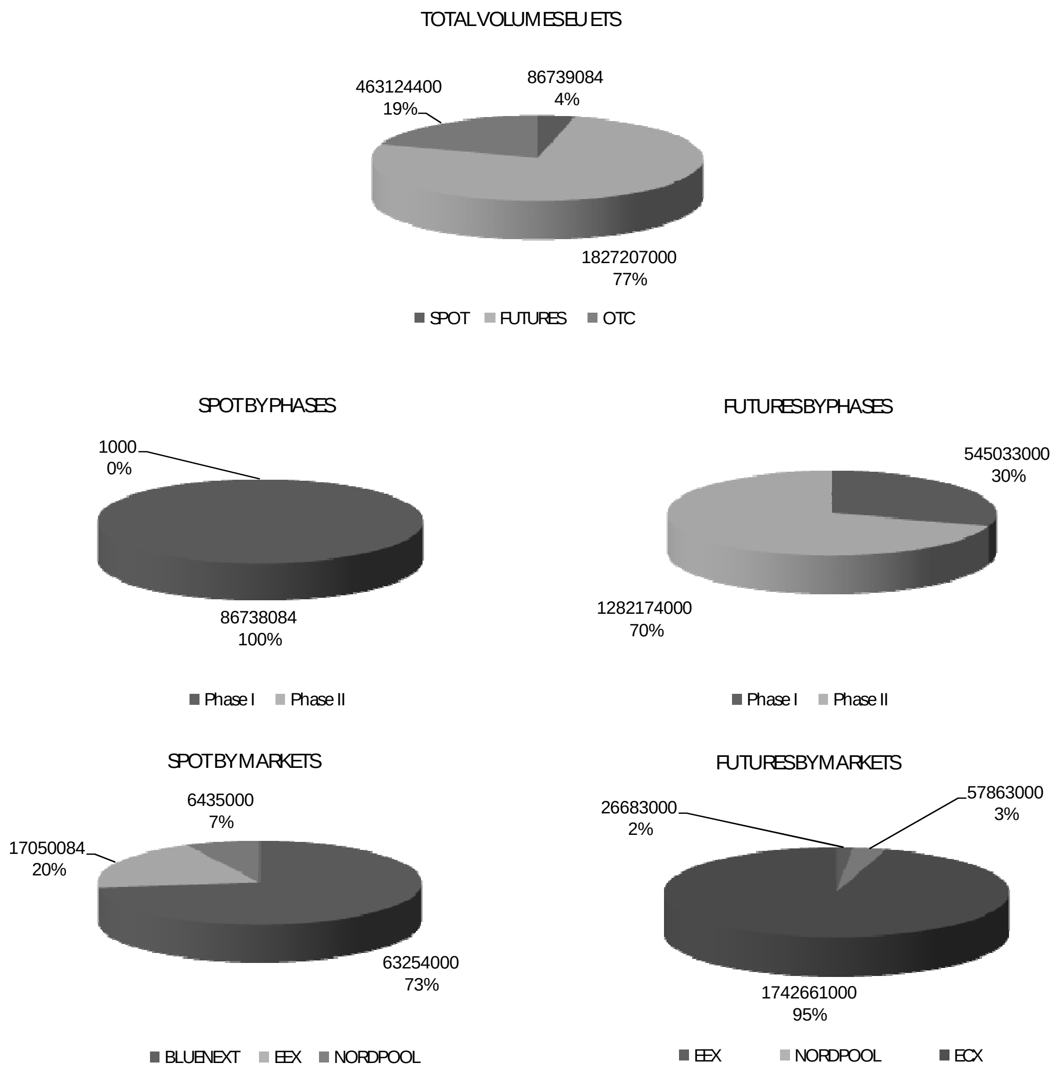
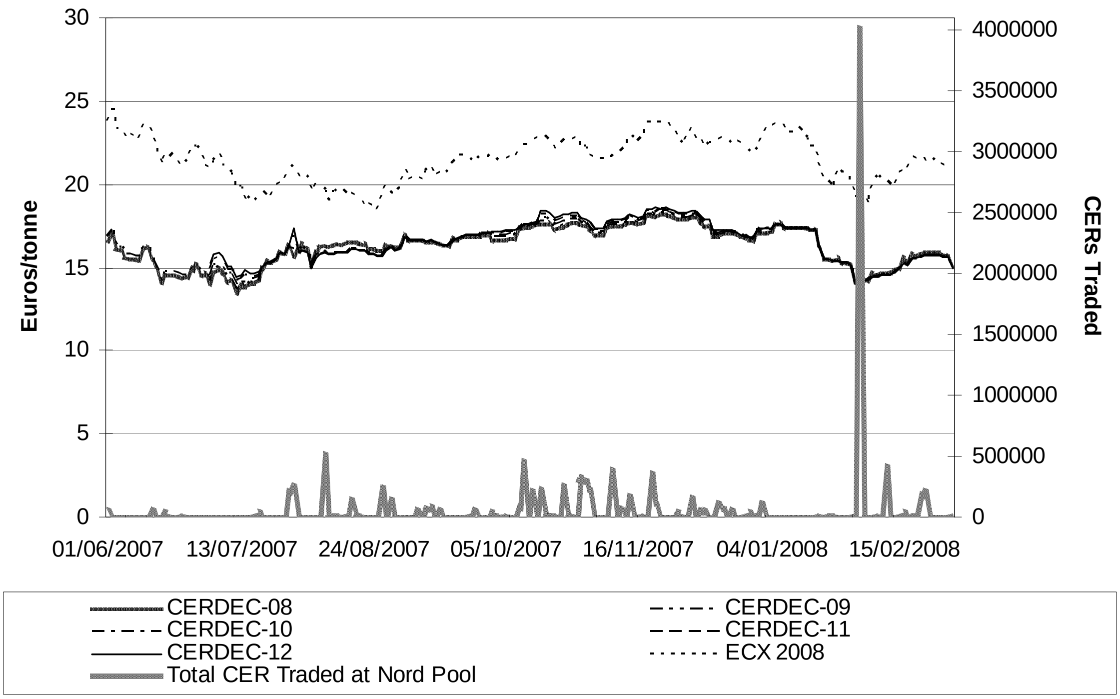


Figure 7: Certificate Emission Reduction Futures Prices and Volume in Nord Pool.

This Figure shows the evolution of the CERs prices and the evolution of the Phase II prices since the beginning of the trading of CERs futures contracts in Nord Pool. All CERs prices correspond to CERs futures contracts traded in Nord Pool. All of them expire in December and the number represents the year of the Phase II of the EU ETS. ECX 2008 refers to the futures contract on EUAs traded in the ECX. The total CERs volume traded in Nord Pool expressed in tonnes traded is also presented. S*ource: Nord Pool and ECX web page.*



CHAPTER 2

CO_2 Prices, Energy and Weather

2.1. INTRODUCTION

In the framework of the Kyoto Protocol, the European Union has set up the Emission Trading Scheme (EU ETS) to reduce CO_2 emissions. The EU ETS started on 1st January 2005 and is driven by the 2003/87/EC directive. Under this scheme, European large CO_2 emitting installations receive permits from their government to emit tonnes of CO_2-equivalent that can be traded in several spot, futures, forward and options markets, whenever they fulfil their targets at the scheduled time.

It is important to note that the EU ETS is the framework for the first real market for CO_2 in that a clear scarcity has been created and a broad range of agents are required to possess rights for their use for compliance. Moreover, it is the largest environmental market in the world exceeding the US SO_2 trading program in several areas such as the number of installations, the quantity of emissions covered and the value of assets created and distributed. Specifically, the 2003/87/EC directive covers the energy-intensive installations that represent almost half of Europe's CO_2 emissions. Following such directive, each Member State in the EU has to submit to the European Commission its National Allocation Plan (NAP) in which each Member State determines the total quantity of CO_2 allowances granted per year to its companies for a specified commitment period. In the EU ETS context, the first commitment period is 2005–2007 and the second one, which coincides with the first compliance period of the Kyoto Protocol, is 2008–2012. The third European commitment period will start in 2013.

Although the main objective of the EU ETS is the reduction of emissions, considering Lowrey (2006), perhaps the most important objective is the establishment of a market price for allowances. This means that European CO_2-emitting installations will be aware of the environmental consequences of their polluting activities. The question then is what are the factors that determine the price of CO_2 permits?

In this paper, we analyse empirically the main determinants of 2005 CO_2 prices. As far as we know, this is the first study to do so. Specifically, we rely on the assumptions of theoretical models and on the suggestions made by market agents to guide our study into the weather and non-weather variables that could affect daily CO_2 forward prices. The study will allow us not only to gain insights into the relationship between energy-related variables and CO_2 prices, but also to shed light on the functional form between weather variables and the CO_2 returns. It must be stressed that we are not attempting to explain the average level of prices over the period with respect to expectations but to focus on the daily returns during 2005 in an attempt to examine the underlying rationality of CO_2 pricing behaviour.

This paper is organised as follows. The next section presents a review of the previous literature about the determinants of CO_2 emission allowance prices and the reflections of the market agents on this subject. Section 3 describes the CO_2 markets in Europe including a brief picture of the market-places and contracts, the data description and the justification of the data used in this paper. Sections 4 and 5 describe the energy and weather variables used to explain the behaviour of the 2005 CO_2 prices, respectively. Section 6 presents the results of the joint influence both of non-weather and weather variables on CO_2 prices. The last section summarizes the paper with some concluding remarks.

2.2. THE DETERMINANTS OF CO_2 PRICES

If we look to the literature, we find that the various models give different answers to the question of what factors influence CO_2 allowance prices, as they focus on different aspects of the effects of emission trading on the economy. Until now, the most complete reference on this subject has been the survey by Springer (2003). That paper gathered results from 25 models of the market for tradable greenhouse gases emission permits. The spectrum of estimated permit prices ranges from 1 to 74 US$ per tonne CO_2-equivalent. Among the coincident factors that determine the long-term CO_2 emission allowance prices, the authors consider microeconomic and macroeconomic factors (characteristics of the energy sector, GDP growth, emission growth and emission target), energy factors (price of energy sources and energy substitutability possibilities) and climate factors (temperature and climatic conditions).

It is important to note that these factors, proposed by theoretical models, are generally consistent with market agents' perceptions. Firstly, Point Carbon, Powernext and RK Consulting consider macroeconomic, microeconomic and weather factors as being the main determinants of CO_2 prices.[33] Secondly, energy factors, such as the price of oil, natural gas and electricity as well as temperature and rainfall are quoted in most of the "*Weekly summary of emissions market*" published by Enervia.[34] Finally, the European Climate Exchange jointly with the Chicago Climate Exchange and Point Carbon, in their report entitled "*What determines the price of carbon in the European* Union?" by Christiansen and Arvanitakis (2004), argue that the way to forecast price trends is to assess three fundamental aspects: policy and regulatory issues, market fundamentals and

[33] See http://www.pointcarbon.com, www.powernext.fr and http://www.carbonriskmanagement.com.
[34] http://www.enervia.com/.

technical analyses. In the role of fundamentals they consider both the supply of allowances and the demand for allowances, which are in turn a function of CO_2 production levels.

Attention must be paid to the fact that the theoretical models are not appropriate when explaining the change of daily prices. Those models are usually silent with respect to weather and are relevant to understanding year by year changes or underlying market forces, but of no help with daily fluctuations. However, these models shed light into what variables can be used to explain short-term CO_2 prices. Daily energy prices and weather data have been used in this paper by applying methodology that is similar to that followed in studies of determinants of other weather dependent variables such as the price of electricity (Longstaff and Wang (2004) and Stevenson et al. (2006)), the price of gas (Bopp (2000)) and the price of orange futures contracts (Roll (1984) and Boudoukh et al. (2005)).

In particular, to explain the main determinants of carbon prices we have considered the supply of European Union Allowances (EUAs) and factors that affect European CO_2 production such as weather variables (temperature and rainfall) and energy-related variables (oil price, gas price, coal price and fuel switching from gas to coal).

2.3. CO_2 MARKETS IN EUROPE

There are several organized market places in Europe where it is possible to trade EUAs, which are defined as the right to emit one tonne of CO_2-equivalent. Specifically, EUAs can be traded in spot markets such as Powernext (Paris), Energy Exchange of Austria (EXAA, Vienna), Nord Pool (Oslo) and European Energy Exchange (EEX, Leipzig).

There is also a pan-European platform called Climex Alliance where it has been possible to trade spot contracts since July 2005. Furthermore, Nord Pool, European Climate Exchange (ECX/IPE, London) and EEX markets have futures contracts with EUAs as the underlying commodity. [35]

It must be pointed out that not all the CO_2 trading is done in organized markets. The European Energy Exchange (EEX) soon calculated an index of over-the-counter (OTC) forward CO_2 prices, called *CO_2 Index* or *European Carbon Index*. This index has been published and provided on each trading day from 25th October 2004 to 30th November 2005. The index is a volume-weighted average price of OTC forward trading activities of market participants with delivery until 30th April 2006. A second OTC carbon index has been created by the London Energy Brokers' Association (LEBA). LEBA is comprised of 10 members, who together provide coverage for all key product groups in the energy sector: oil, gas, power, coal and emissions. The *LEBA Carbon Index* is a volume weighted index that takes into account all carbon deals transacted through the LEBA member firms. Although both OTC indices are highly representative, the LEBA Carbon Index has a shorter history given that it has been published since the end of March 2005.[36]

Figures 1-A and 1-B compare the evolution of the *European Carbon Index* with the price series of spot and future markets, respectively. The first future contract traded in

[35] For additional information about these markets see the official web pages of the CO_2 markets in Europe: CLIMEX (www.climex.com), EEX (www.eex.de), ECX/IPE (www.theipe.com), EXAA (www.exaa.at/cms), Nord Pool (www.nordpool.no) and Powernext (www.powernext.fr).
[36] The cross correlation between the European Carbon Index and the LEBA Carbon Index, from April to November 2005, was 99.74%. For further information about the European Carbon Index see www.eex.de. For further details concerning LEBA Carbon Index see www.leba.org.uk.

Nord Pool took place on 11th February 2005 and the first spot contract traded in EEX took place in March 2005. Note that the trades in OTC markets started in October 2004.

If we observe the CO_2 prices, we can see that there was an initial period when prices were low and stable. Specifically, the *CO_2 Index* price was around 8 €/tCO_2 before the EU ETS started in January 2005. The price bottomed out at its lowest level (6.65 €/tCO_2) on 17th January 2005, and then it increased, reaching a peak (29.3 €/tCO_2) on 7th July 2005. Finally, the price decreased to reach the 20 €/tCO_2 level, and it remained in the 20 to 25 €/tCO_2 range until maturity in November 2005.

As we can see, the CO_2 prices trends are very similar in both figures. This fact can be confirmed with a cross correlation analysis in prices and returns between the *European Carbon Index* and spot markets (Panel A of Table 1) and between the *European Carbon Index* and futures markets (Panel B of Table 1).[37]

All the contemporary correlation coefficients are statistically significant at the 5% level. The positive and significant correlation coefficients indicate that all markets are strongly correlated and all of them incorporate the information in a very similar way.[38] Given that we are interested in the most representative series of EUA prices, we have chosen the longest price series that belongs to the *European Carbon Index* from the EEX market. According to the applicable rules for EEX OTC forward contracts on EUAs, trading ended on 1st December 2005. Therefore, our sample period runs from the formal launch of the EU ETS on 1st January 2005 to the expiration of the *European*

[37] As we justify in Section 4, the return has been defined as $r_t=ln(P_t/P_{t-1})$, where P_t is the price series at time t.

[38] Since in the EXAA market the trading takes place only once a week, it has been eliminated from the correlations of prices and returns as the number of observations is very small. Climex Aliance has also not been included since no data is available.

Carbon Index on 30th November 2005 (233 observations). The study then focuses on which are the determinants of CO_2 daily forward prices for the year 2005, the first year of compliance.

2.4. ENERGY-RELATED DATA

Following the conclusions of section 2, we have considered the most representative prices of oil, natural gas and coal in Europe in order to explain the 2005 daily EUA OTC forward prices. In all cases, to better take into account the trend of expectations on prices over the year, we have chosen the daily energy forward prices with the closest maturity to the expiration of the *European Carbon Index*. Thus, our sample period consists of daily futures prices of Brent and Natural Gas, both traded at International Petroleum Exchange (IPE) and coal forward prices published by Tradition Financial Services (TFS), a broker association that provides the TFS API 2 index, which is the reference price of coal in Europe.[39]

The futures contract on Brent is quoted in US$ per barrel, the futures contract on Natural Gas is quoted in GBP per therm and the coal contract is quoted in US$ per metric tonne. To carry out the study, we have converted them into euros using the daily exchange rate data available from the European Central Bank.[40]

All the price series, including CO_2 OTC forward prices, present a unit root and they have been converted into stationary taking first natural logarithm differences.[41] That is, we have carried out our study using continuous compounded returns constructed as

[39] Specifically, the coal prices (TFS API 2) are CIF (Cost, Insurance and Freight) with delivery in ARA (Amsterdam, Rotterdam and Antwerp).
[40] See http://www.ecb.int.
[41] These results are presented in Annex I.

$r_{it}=ln(P_{it}/P_{it-1})$, where P_{it} is the i-th price at time t and where i = c (CO_2), g (Natural gas), b (Brent) and cl (Coal). As a background, Table 2 presents the cross correlations between the returns both on CO_2 and the energy variables, which can give us a preliminary idea about the explanatory power of the latter ones.

As we can see in Panel A of Table 2, only the contemporaneous cross correlation coefficients of gas (19.5%) is positive and statistically different from zero at the 5% level. It is interesting to note the unexpected result of the absence of a contemporaneous correlation between Brent and coal with CO_2 returns.

We also present the same analysis between CO_2 returns and the returns of energy variables lagged one period. As we can appreciate in panel B of Table 2, there is no significant relationship between CO_2 returns and the returns of coal lagged one period. In contrast, the statistically significant correlations between the lagged energy variables and CO_2 returns are much higher than in the case of the contemporaneous variables. The correlation between CO_2 returns and Brent returns lagged one period is 26.8% and between gas returns lagged one period is 21.6%. These results indicate that a model that tries to explain CO_2 returns should take into account not only contemporaneous information but also past information about energy prices.

Following Lowrey (2006) *"if the price of gas increases relatively to the price of coal, then the cost of cutting emissions by switching from gas to coal increases and – other things being equal – the demand for coal will increase. Therefore, the demand for carbon allowances to cover that generation will also rise, leading to a resultant increase in emission allowance prices"*. A similar idea is pointed out in Christiansen and Arvanitakis (2004). In order to incorporate this switching effect in our study, we have introduced into the model a variable called $Ratio_t$, defined as the quotient between Gas returns and coal returns.

2.5. WEATHER DATA

2.5.1. Variables description

As discussed in section 2, the carbon price should depend on, among other factors, energy consumption. Furthermore, energy demand is affected by the climate (see Le Comte and Warren (1981), Li and Sailor (1995) and Peirson and Henley (1994)). For both reasons, we have considered weather variables as possible determinants of the EUA prices and we have analyzed whether they can help to explain its behaviour.

On the one hand, we have focused on weather data from Germany. The reason for such choice is twofold. Firstly, the CO_2 price series used in the study are OTC forward prices that result mostly from the trade among those German market participants that are concerned about the weather in Germany.[42] Secondly, Germany is the largest national market for electricity in Europe after Russia. In fact, Germany represents the biggest National share of EUAs allocated in Europe (23.6%).

On the other hand, although Germany is the largest power producer/consumer of the EU-25, it covers only a minor part of the total power supply/demand in the EU. Countries such as Spain, Portugal and Italy constitute an important share of European demand and the weather variables in those countries can have a different impact on power supply than German weather variables. For these reasons, in order to detect the

[42] See http://www.eex.de/index.php?page=55.

influence from weather events representative of the entire geographic extent of the EU ETS, we have also used a more comprehensive index of the weather variations throughout the EU ETS market area.

Following the suggestions by the World Meteorological Organization (WMO, 1983), the German weather variables considered in this study are the following: the minimum air temperature (ºC), the mean air temperature (ºC), the maximum air temperature (ºC) (all temperatures are measured two meters above the ground), and the rainfall precipitation (mm). The data has been provided by the *Deutscher Wetterdienst,* which has public and available data of weather variables for 44 meteorological stations across Germany.[43]

To complete the blanks of those data series, the correlation between the same series of the nearest stations has been calculated. When the correlation is lower than 80%, the half point between the previous and the subsequent data of the series has been calculated to fill the blanks. However, when the correlation is higher than 80%, a regression has been estimated between both stations and the blanks have been completed using the information from the regression.

In the case of the European weather index, we have used the daily data provided by Powernext. These variables are the mean temperature for the following countries: Belgium, Spain, France, Italy, Germany, United Kingdom, Portugal and The Netherlands. For each country, some important cities have been considered as representative cities. The mean temperature index has been calculated as the average

[43] Details of how those variables are calculated by the *Deutscher Wetterdiens*t can be found at http://www.dwd.de/en/en.htm.

temperature of those cities weighted by the population of the area they represent In the case of there being no value for the weather station in the city, two replacement stations have been chosen in order to fill the gaps. The stations have been selected according to both the geographical proximity and the value of the coefficient of correlation with the station of reference.[44]

2.5.2. Indices construction

To take into account the impact of climate on the aggregated CO_2 emission allowance returns, we follow the methodology proposed by Valor et al. (2001). We have constructed weather population-weighted indices for the different weather series considered. In particular, the indices have been defined as follows:

$$IX_t = \sum_{s=1}^{n} X_{st} w_{st}$$

where IX_t is the X meteorological variable index on day t, X_{st} is the value of the climate variable in the station s on day t, w_{st} is the population weight of the area assigned at each station and n the number of stations.[45]

To elaborate the indices representing the weather in Germany, eight of the 44 stations have not been considered because their population was not representative compared with the total population of Germany.[46] Furthermore, the station of Fritzlar was also eliminated from the sample because there were too many blanks in the data that could

[44] www.powernext.fr.
[45] The population data of Germany has been obtained from the "Statistische Ämter des Bundes und der Länder" at http://www.statistik-portal.de and the population data for the European indices has been obtained from Eurostat at http://epp.eurostat.ec.europa.eu.
[46] These are: Helgoland, List, Westermakelsdorf, Kahler Asten, Nürburg-Barweiler, Fichtelberg, Zugspitze and Hohenpeißenberg.

not be completed with reliability (and also, its population was not very significant in global terms). As a consequence, the indices have been calculated with 35 stations. It is important to highlight that these indices reflect the overall weather in Germany as all the stations considered are distributed across Germany, they are located in different climatic zones, and all large German cities are taken into account.

For the weather in Europe, we have calculated a weather index representing the mean temperature in Europe from the eight series provided by Powernext.

2.5.3. Weather influences

In order to analyze the individual impact of weather variables in the CO_2 emission allowance returns, we have separated the carbon returns by considering extreme weather conditions and their persistence for each of the three climatologic variables (air temperature and rainfall precipitation in Germany and air temperature in Europe). In particular, we define a day as extremely dry (cold) if all the daily rainfall (temperature) indices of up to a maximum of five consecutive previous days are in the first quintile. Note that in the case of air temperature for Germany, the indices of the minimum air temperature and the maximum air temperature have been used in order to better distinguish the extreme weather. That is, the quintiles have been calculated from these series and the lower and upper quintiles have been chosen to construct the dummy variables representing the extreme temperature.

If weather has an influence on CO_2 returns, the weather extremes will present abnormal returns and their signs would depend on which climatologic variable we are considering. For example, if temperature influences carbon prices, both the hot and cold days will present abnormal and positive returns. The energy use in extreme weather is higher than in moderate weather. When there is extremely cold weather the use of heating is larger, leading to an increase in energy consumption that provokes the raising of allowance prices as a result of the larger CO_2 emissions. In the case of extremely hot weather, the increase in energy use would be caused by a jump in the use of air conditioning.

Similarly, if rainfall affects carbon prices, the rainy (dry) days will present abnormal and negative (positive) returns. The explanation is that with high (low) precipitation levels, the possibility of producing hydroelectricity is larger (smaller) than without (with) them and so it is (not) possible to switch energy production from an intensive emission source to a non-intensive emission one. As a consequence, a reduction (rise) of real emissions would take place and the prices of emission allowances would decrease (increase).

To test the presence of abnormal returns, we apply the non-parametric Kruskal-Wallis statistic that makes no distributional assumptions on returns and test the null hypothesis of equality of the medians between the extreme quintile and the remaining observations. Additionally, to check that the number of observations belonging to the extreme quintile is randomly drawn from the total number of observations, an additional non-parametric test has been performed. Thus, we have calculated the χ^2-statistic that tests the null hypothesis that the expected frequency of positive or negative return days among the observations in the chosen quintile equals the realised frequency of positive or negative return days among all the observations of the period. More specifically, the test statistic used is the square of the observed frequency (O_j) with respect to the estimated frequency (E_j), weighted by the estimated frequency. The test criterion is:

$$\chi^2 = \sum_{j=1}^{k} \frac{(O_j - E_j)^2}{E_j}$$

where k is the number of categories.

Table 3 presents the results for rainfall precipitation and air temperature in Germany, while Table 4 shows the results for air temperature in Europe. In relation to temperature in Germany (Panels A and B in Table 3), we can appreciate that both extreme variables, the one representing the persistent cold days and the other representing the persistent hot days, have statistically significant higher medians. That is consistent with what we would expect. The χ^2 – statistic test results for this variable are quite different. Only in the case of extremely hot weather and with a persistence of at least three days, can we say that there are statistically more positive returns in the last quintile than in the rest of the sample. Nevertheless, although the frequency of positive returns in the first quintile are not statistically different from the frequency of positive returns in the rest of the sample for the extremely low temperatures, given that the median is still statistically larger (Kruskal-Wallis test), we would expect a positive and significant effect of extremely low temperatures on CO_2 returns.

In the case of rainfall (Panels C and D in Table 3), we would expect that extremely high precipitation levels would lead to a decrease in prices and thus negative returns. The empirical results of Kruskal-Wallis tests for both cases confirm these expectations. On the one hand, when considering extremely dry days, the median values are statistically larger in the first quintile than in the rest of the sample in the case of persistence up to three days. With persistence longer than three days, we do not observe statically significant differences in medians. On the other hand, when analyzing extremely rainy days, there are not enough observations when considering long persistence (four and five consecutive rainy days) and for this reason the results have to be taken with care. If we consider persistence up to three days, the median values are statistically smaller.

Table 4 exhibits the results for the European weather. Panel A shows the results for extremely low temperatures (the first quintile of the mean air temperatures) and Panel B presents them for extremely high temperatures (the last quintile of the mean air temperatures). Only in the case of high temperatures (Panel A) does the χ^2– statistic test lead to more positive returns in the last quintile than in the rest of the sample. The Kruskal-Wallis tests reflect that the medians of the quintiles and the medians of the remaining samples are not statistically different. One reason that could explain these results is that when we consider a European weather index, the extremes are smoothed out and they are not different enough from the rest of the sample.

2.6. WEATHER AND NON-WEATHER INFLUENCES

Following Christiansen and Arvanitakis (2004), the price of CO_2 emission allowances depends on both the demand and supply of allowances. For the first European commitment period, the supply of allowances is capped by the EU ETS through the NAPs. As we have mentioned, the NAP is the document in which each European Government decides how many allowances will be distributed among the companies affected by the 2003/87/EC directive of the European Union. However, the market supply is the total of all the allowances that companies decide to offer. Therefore, the key issue is to what extent the agents anticipate the real amount. The differences between the expectation and the real amount will provoke real variations in prices. Most of the plans for the first commitment period (2005-2007) were approved by the European Commission before 2005. Only five countries submitted the Allocation Plans during 2005.[47] The impact on CO_2 emissions allowance prices' of these five Allocation Plans has been studied through an intervention analysis and the results were not statistically significant. One possible explanation for this is that since the NAPs should have been approved by the European Commission in 2004, the effect had probably already been discounted by the agents. Therefore, we will focus on those aspects that the literature and the market agents indicate that influence the demand for CO_2 emission allowances.

In order to capture the effects of energy related variables on CO_2 prices, and taking into account the effects considered before, we have performed multivariate linear regressions using the least squares method. We have estimated the equation by applying the Newey-West covariance matrix estimator that is consistent in the presence of heteroskedasticity and autocorrelation. In particular, we have implemented the following model with dynamics in the energy variables:

$$r_{c,t} = \alpha_1 + \beta_1(L) r_{g,t} + \delta_1(L) r_{b,t} + \phi_1(L) r_{cl,t} + \gamma_1 Ratio_t + \eta_1 D_{\max,t} + \varphi_1 D_{\min,t} + \varepsilon_t \qquad (1)$$

where $r_{c,t}$ is the CO_2 returns series, $r_{g,t}$ is the gas returns series, $r_{b,t}$ is the Brent returns series, $r_{cl,t}$ is the coal returns series, t refers to the time considered, α_1 is the constant, $\beta_1(L)$ is the lag polynomial related to the gas, $\delta_1(L)$ is the lag polynomial related to

[47] The National Allocation Plans approved in 2005 by the European Commission are those of the following countries: Czech Republic and United Kingdom (12/04/2005), Poland (08/03/2005), Italy (25/05/2005) and Greece (20/06/2005).

Brent, $\gamma_1(L)$ is the lag polynomial related to coal; $D_{max,t}$ and $D_{min,t}$ are two dummy variables that eliminate the effect of three positive and three negative extreme CO_2 returns respectively.[48] ε_t is the error term of the regression.

Additionally, we have introduced in the model the variable defined as $Ratio_t$, calculated as the quotient between the gas return and the coal return, in order to capture the switching possibilities between gas and coal.

We have conducted the analysis taking into account different lags for Brent, gas and coal returns. The picture is very similar in all the scenarios and, in order to simplify the exposition, we present only the results for one lag. The results of the model (1) are reported in Table 5. The coefficients and their *t statistics* are shown in Panel A while the R^2, the *Adjusted* R^2, the *Akaike Infromation Criteria* (AIC) and the *Schwarz Criteria* (SC) are presented in Panel B.

The coefficients of the three contemporaneous energy variables are not statistically significant at the 5% level. However, the coefficient for lagged Brent returns is statistically significant at the 1% level and the coefficient for gas lagged returns is statistically significant at the 5% level. Both of them are positive and therefore they are consistent with what we would expect, that is to say, the return of CO_2 emission allowances increase with Brent and gas returns. Surprisingly, neither the coal returns (contemporaneous and lagged) nor the quotient between the gas returns and the coal returns are statistically significant. Finally, the dummy variables are also statistically

[48] Given that the market is immature, we have estimated the model controlling for the extreme CO_2 movements. The CO_2 returns considered are the three highest (that correspond to the days 10/01/2005, 14/07/2005 and 22/07/2005) and the three lowest (that correspond to the days 21/03/2005, 22/03/2005 and 04/04/2005) of the sample.

significant; this means that the three extreme positive and three negative values help to explain the series of CO_2 returns.

The estimated model does not include weather variables as regressors. To capture jointly the effects of weather and energy-related variables on CO_2 returns, we follow the line proposed by Roll (1984) where temperature and rainfall data are used to model the futures returns in frozen concentrated orange juice. Roll (1984) finds little evidence of an influence of weather on the price of the contracts. Boudoukh et al. (2005), in a later article, show the difficulty in introducing weather into a model to explain the returns of frozen concentrated orange juice contracts commented on above. They present some models where the temperature is introduced in different ways in order to find some evidence of the impact of this variable. In this case, the authors find larger impacts of temperature than in the case of Roll (1984), and they attribute those impacts to the non-linear structure of the different models considered. In our study, we firstly include the weather variable in a linear form, but we also introduce dummy variables reflecting extreme weather conditions. Those variables are similar to some dummies taken into account in Boudoukh el al. (2005) and we introduce them in order to collect possible non-linearity influences of weather variables.

Firstly, we estimate the model taking into account the German weather and secondly, we estimate the model considering the European weather. The estimated model for the case of Germany is given by:

$$\begin{aligned} r_{c,t} = {} & \alpha_2 + \beta_2(L)r_{g,t} + \delta_2(L)r_{b,t} + \phi_2(L)r_{cl,t} + \gamma_2 Ratio_t + \eta_2 D_{\max,t} + \varphi_2 D_{\min,t} + \kappa_2 Tm_t + \\ & + \mu_2 D_{T\max,t} + \theta_2 D_{T\min,t} + \nu_2 RR_t + \varpi_2 D_{RR\max,t} + \omega_2 D_{RR\min,t} + \varepsilon_t \end{aligned} \quad (2)$$

where Tm_t is the index series of mean air temperature, $D_{Tmax,t}$ is the dummy related to the extremely high temperature, $D_{Tmin,t}$ is the dummy referring to the extremely low temperature, RR_t is the total precipitation index, $D_{RRmax,t}$ is the dummy that reflects the extremely rainy days, $D_{RRmin,t}$ is the dummy that captures the extremely dry days and ε_t is the error term. All climate dummy variables take into account the three-day persistence of the climatology effect in Germany (see Table 3).

The results of this model are presented in equation (2) of Table 5. The adjusted R^2 increases from 41.50% to 47.81%; the AIC decreases in relation to the equation (1) and the SC remains the same. Therefore, the weather influence is relevant on CO_2 returns. The coefficients of the Brent and gas lagged returns are still statistically significant at the 5% level; the size of the former decreases slightly in relation to the regression (1) while the coefficient of the latter increases. The coefficient of the variable $Ratio_t$ is still not statistically significant. With regard to weather variables, we observe that the mean temperature index, the total precipitation index, the rainy days and the dry days do not have significant influence on the CO_2 returns. However, we find that both dummy variables related to the extreme temperatures are statistically significant at the 1% level. The impact of these variables on the CO_2 returns is positive, which means that the prices of CO_2 increase with extremely hot and cold days. As explained in section 5.3, this is consistent with what we would expect.

Following Boudoukh el al. (2003) we have also considered additional scenarios which take into account the distance of the daily temperature of the previous day from the reference temperature that separates the heating degree-days and the cooling degree-days. Different reference temperatures have been considered and the results obtained were always very similar to the results obtained with the dummy variables related to the temperature considered in this study.

In order to consider the weather in Europe, we take out the series of German weather in the model in Equation (2) and introduce in their place the series for the weather in Europe. The model for the case of European weather is given by:

$$\begin{aligned} r_{c,t} = \alpha_3 + \beta_3(L)r_{g,t} + \delta_3(L)r_{b,t} + \phi_3(L)r_{cl,t} + \gamma_3 Ratio_t + \eta_3 D_{\max,t} + \varphi_3 D_{\min,t} + \\ + \kappa_3 Tm^E{}_t + \mu_3 D^E{}_{T\max,t} + \theta_3 D^E{}_{T\min,t} + \varepsilon_t \end{aligned} \quad (3)$$

where $Tm^E{}_t$ is the European index series of mean air temperature, $D^E{}_{Tmax,t}$ is the dummy related to the extremely high temperature and $D^E{}_{Tmin,t}$ is the dummy referring to the extremely low temperature.

The results of this model are presented in Equation 3 of Table 5. The R-adjusted decreases in relation to Equation 2 because the three European weather variables are not statistically significant. Therefore, the AIC and the SC are larger than in the other equation.

To better understand these results, we have to take into consideration two facts. First, the use of the mean air temperature in Europe to obtain the dummy variables does not capture the extreme weather as properly as the maximum and the minimum air temperature used in the case of Germany. Second, if we calculate a European weather index, the extreme weather will be smoothed because the climate in the North and in the South countries is balanced. Furthermore, it is important to remember that the vast majority of trading participants in the EEX market during the sample analyzed were German companies that are concerned with the German weather.

2.7. SUMMARY AND CONCLUDING REMARKS

Most of the theoretical models dealing with the factors that determine CO_2 prices suggest that energy prices and weather factors could influence allowance prices. These factors are, in general, consistent with market agents' perceptions. In this paper we focus on the daily CO_2 returns during 2005 in an attempt to examine the underlying rationality of pricing behaviour. In particular, in this study we analyse several models to corroborate the influence of energy and weather variables on CO_2 returns.

The results show that the most important variables in the determination of CO_2 returns are the Brent and natural gas returns. We also find evidence that extremely hot and cold days in Germany have a positive influence on CO_2 prices. In contrast, we also find some counter-intuitive results such as the fact that neither the price of the most intensive emission source (coal) nor the switching effect between gas and coal returns affect CO_2 returns. Nevertheless, all the variables that are statistically significant influence the carbon returns in the sense we would expect and therefore, we find some evidence of the rationality of this market, that is, the daily forward prices do reflect underlying conditions at the micro-level and so carbon markets are not as irrational as some participants and observers have suggested.

Table 1: Cross Correlation coefficients.

This table presents a cross correlation analysis in prices and returns between the *European Carbon Index* and spot markets (Panel A) and between the *European Carbon Index* and futures markets (Panel B). Sample period consists of data from 1st January 2005 to 30th November 2005. CO_2 index is the OTC future contracts index calculated by EEX, Powernext refers to the spot prices in Powernext, Nord Pool to spot prices in Nord Pool, while Nord Pool_05 refers to the future contract maturing in 2005, Nord Pool_06 in year 2006 and Nord Pool_07 in year 2007. ECX refers to the future prices in ECX with maturity in 2005, EEX_06 refers to the future prices in EEX with maturity in 2006 and EEX_07 to the future prices in EEX with maturity in 2007. The critical value for the statistical significance of the correlation coefficient is calculated as $2/n^{1/2}$. All the coefficients are statistically significant at the 5% level.

Panel A: *European Carbon Index* and Spot Markets

Prices	POWERNEXT	NORD POOL
CO_2 Index	0.979	0.969
POWERNEXT	1.000	0.993
NORD POOL		1.000

Returns	POWERNEXT	NORD POOL
CO_2 Index	0.611	0.616
POWERNEXT	1.000	0.854
NORD POOL		1.000

Panel B: *European Carbon Index* and Futures Markets

Prices	NORD POOL_05	NORD POOL_06	NORD POOL_07	ECX	EEX_06	EEX_07
CO_2 Index	0.951	0.945	0.943	0.965	0.976	0.975
NORD POOL_05	1.000	0.996	0.993	0.993	0.987	0.986
NORD POOL_06		1.000	0.999	0.988	0.992	0.992
NORD POOL_07			1.000	0.988	0.992	0.992
ECX				1.000	0.989	0.989
EEX_06					1.000	0.999
EEX_07						1.000

Returns	NORD POOL_05	NORD POOL_06	NORD POOL_07	ECX	EEX_06	EEX_07
CO_2 Index	0.626	0.645	0.644	0.503	0.651	0.643
NORD POOL_05	1.000	0.945	0.971	0.764	0.829	0.812
NORD POOL_06		1.000	0.960	0.673	0.840	0.824
NORD POOL_07			1.000	0.751	0.863	0.851
ECX				1.000	0.465	0.454
EEX_06					1.000	0.996
EEX_07						1.000

Table 2: Correlations of CO_2 and energy variables returns.

Panel A of this table shows the correlation coefficients between the CO_2 returns and the energy variables returns. Panel B reports the correlation coefficients between energy variables returns lagged one period and the CO_2 index returns as well as the correlation among the energy variables and the energy variables lagged one period. $r_{c,t}$ refers to returns of CO_2 index traded at EEX, $r_{b,t}$ are the returns of Brent futures traded at IPE, $r_{g,t}$ the returns of Natural Gas futures traded at IPE and $r_{cl,t}$ the returns of coal futures published by TFS, $r_{c,t-1}$ are the returns of *CO_2 index* traded at EEX lagged one period, $r_{b,t-1}$ are the returns of Brent futures traded at IPE lagged one period, $r_{g,t-1}$ are the returns of Natural Gas futures traded at IPE lagged one period, and $r_{cl,t-1}$ the returns of coal futures published by TFS, also lagged one period. 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.

Panel A

	$r_{c,t}$	$r_{b,t}$	$r_{g,t}$	$r_{cl,t}$
$r_{c,t}$	1.000*			
$r_{b,t}$	0.093	1.000*		
$r_{g,t}$	0.195*	0.139*	1.000*	
$r_{cl,t}$	0.055	0.024	- 0.073	1.000*

Panel B

	$r_{c,t}$	$r_{b,t}$	$r_{g,t}$	$r_{cl,t}$
$r_{c,t-1}$	0.202*	- 0.002	0.030	0.140*
$r_{b,t-1}$	0.268*	- 0.067	0.042	0.065
$r_{g,t-1}$	0.216*	0.033	0.247*	0.118
$r_{cl,t-1}$	0.010	- 0.030	- 0.103	0.102

Table 3: Carbon returns and extreme weather conditions in Germany.

The different panels in this table show the same information for different extreme weather variables in Germany. Panel A shows the results for extremely low temperatures (the first quintile of the minimum air temperatures), Panel B for extremely high temperatures (the last quintile of the maximum air temperatures), Panel C for extremely low rainfall precipitation and Panel D for extremely high precipitation. The first column of each panel reports the days of persistence from one to five consecutive days of extreme weather. The next three columns are related to the first or last percentile (depending on where the data of extreme weather is situated). The number of observations, the percentage of positive returns in that percentile and the median of the returns of the percentile are shown. The next two columns refer to the rest of the sample. The first one shows the number of returns in the rest of the sample and the second one the median of these observations. The last two columns are the results of the two non-parametrical tests. K-W is the column of the Kruskal-Wallis test and χ^2 the results of the χ^2-statistic test. * denotes statistical significance at 1% and ** at 5% .

Panel A: Low Temperaturas

	$r_c > 0$ and first quintile			Remaining observations		Tests	
	Num. Obs	% r>0 in first quintile	Median	Num. Obs	Median	K-W Value	χ^2 Value
5d	18	64.28%	1.88%	215	0.26%	14.5816*	0.5950
4d	21	63.63%	2.02%	212	0.22%	16.6702*	0.4077
3d	23	60.52%	2.02%	210	0.22%	17.6958*	0.0000
2d	26	61.90%	1.52%	207	0.19%	15.9548*	0.0808
1d	29	64.44%	1.30%	204	0.18%	16.7*	0.6462

Panel B: High Temperaturas

	$r_c > 0$ and last quintile			Remaining observations		Tests	
	Num. Obs	% r>0 in last quintile	Median	Num. Obs	Median	K-W Value	χ^2 Value
5d	13	72.22%	0.57%	220	0.39%	2.5756	5.736**
4d	15	71.42%	1.02%	218	0.36%	4.7267**	4.9847**
3d	18	72%	1.93%	215	0.27%	8.5658*	5.5203**
2d	20	64.51%	1.77%	213	0.27%	8.6158*	0.6700
1d	27	65.85%	1.86%	206	0.18%	13.299*	1.1928

Panel C: Low rainfall

	$r_c > 0$ and first quintile			Remaining observations		Tests	
	Num. Obs	% r>0 in first quintile	Median	Num. Obs	Median	K-W Value	χ^2 Value
5d	5	35.71%	0.64%	228	0.42%	0.28790	25.7415*
4d	9	47.36%	0.64%	224	0.39%	1.7729	7.2332**
3d	15	51.74%	0.87%	218	0.31%	5.9508**	3.2342
2d	25	58.13%	0.82%	208	0.18%	7.3789*	0.2362
1d	38	57.57%	1.00%	195	0.12%	17.9394*	0.3616

Panel D: High rainfall

	$r_c < 0$ and last quintile			Remaining observations		Tests	
	Num. Obs	% r<0 in last quintile	Median	Num. Obs	Median	K-W Value	χ^2 Value
5d	0	-	-	233	-	-	-
4d	1	33.33%	-10.67%	232	0.42%	2.8727	1.1819
3d	2	28.57%	-8.17%	231	0.42%	5.3724**	4.2649**
2d	7	28.88%	-1.59%	226	0.48%	10.8297*	0.0029
1d	17	36.17%	-1.59%	216	0.59%	22.1720*	0.2545

Table 4: Carbon returns and extreme weather conditions in Europe.

The different panels in this table show the same information for different extreme weather variables. Panel A shows the results for extremely low temperatures (the first quintile of the mean air temperatures) and Panel B for extremely high temperatures (the last quintile of the mean air temperatures). The first column of each panel reports the days of persistence from one to five consecutive days of extreme weather. The next three columns are related to the first or last percentile (depending on where the data of extreme weather is situated). The number of observations, the percentage of positive returns in that percentile and the median of the returns of the percentile are shown. The next two columns refer to the rest of the sample. The first one shows the number of returns in the rest of the sample and the second one the median of these observations. The last two columns are the results of the two non-parametrical tests. K-W is the column of the Kruskal-Wallis test and χ^2 the results of the χ^2-statistic test. * denotes statistical significance at 1% and ** at 5%.

Panel A: Low Temperaturas

	rc > 0 and first quintile			Remaining observations		Tests	
	Num. Obs	% r>0 in first quintile	Median	Num. Obs	Median	K-W Value	χ^2 Value
5d	35	54.29%	0.42%	198	0.42%	0.0384	1.6240
4d	39	56.41%	0.42%	194	0.42%	0.1093	0.7051
3d	43	58.14%	0.18%	190	0.43%	0.0628	0.2362
2d	45	60.00%	0.42%	188	0.42%	0.3151	0.0111
1d	47	59.57%	0.41%	186	0.43%	0.0976	0.0370

Panel B: High Temperaturas

	rc > 0 and last quintile			Remaining observations		Tests	
	Num. Obs	% r>0 in last quintile	Median	Num. Obs	Median	K-W value	χ^2 Value
5d	28	57.14%	0.19%	205	0.45%	0.6039	14.4624*
4d	32	56.25%	0.19%	201	0.45%	0.4592	13.1012*
3d	35	57.14%	0.34%	198	0.43%	0.1534	14.4624*
2d	39	58.97%	0.26%	194	0.45%	0.1936	17.4649*
1d	48	60.42%	0.35%	185	0.46%	0.2173	20.0286*

Table 5: Results of equation (1), equation (2) and equation (3).

Panel A presents the estimates of equation (1), (2) and (3). Equation (1) is the regression of CO_2 returns on energy variables and energy variables lagged one period. Equation (2) is the regression of CO_2 returns on energy variables and German weather variables. Equation (3) is the regression of CO_2 returns on energy variables and European weather variables. $r_{g,t}$ are the gas returns, $r_{b,t}$ are the Brent returns, $r_{cl,t}$ are the coal returns and $r_{g,t-1}$, $r_{b,t-1}$ $r_{cl,t-1}$ are these variables lagged one period. Ratio is the quotient between $r_{g,t}$ and $r_{cl,t}$ .The Dummy variables correspond to the extreme values of the CO_2 returns. $D_{max,t}$ collects the extreme positive returns and $D_{min,t}$ refers to the extreme negative ones. The coefficients of all those variables and the t-statistic are presented in Panel A for equations (1), (2) and (3). In equation (2), the variables added are Tm_t, the mean temperature index for Germany; RR_t the rainfall index for Germany; $D_{Tmin,t}$, the dummy reflecting the extremely low temperature for Germany; $D_{Tmax,t}$ the dummy reflecting the extremely high temperature for Germany; $D_{RRmin,t}$ is the dummy reflecting the extremely low rainfall for Germany and $D_{RRmax,t}$, the dummy reflecting the extremely high rainfall for Germany. In equation (3) the variables added are Tm^E_t, the mean temperature index for Europe, $D^E_{Tmin,t}$ the dummy reflecting the extremely low temperature for Europe and $D^E_{Tmax,t}$ the dummy reflecting the extremely high temperature for Europe. Panel B reports the R^2, the Adjusted R^2, the Akaike Information Critera (AIC) and the Schwarz Criteria (SC). * and ** denotes statistical significance at 1% and 5% level respectively.

Panel A

	Equation 1		Equation 2		Equation 3	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
α_1	0.0020	0.9643	- 0.0068	- 2.003**	- 0.0011	- 0.1403
$r_{b,t}$	0.1371	1.3237	0.1502	1.3905	0.1381	1.3136
$r_{b,t-1}$	0.2792	2.6039*	0.2320	2.2120**	0.2837	2.6154*
$r_{g,t}$	0.0503	0.5742	0.0531	0.6399	0.0534	0.6111
$r_{g,t-1}$	0.1390	2.3433**	0.1223	2.4879**	0.1380	2.2824**
$r_{cl,t}$	0.0533	0.3895	- 0.0143	- 0.1045	0.0575	0.4175
$r_{cl,t-1}$	-0.1278	- 0.8716	- 0.1634	- 1.1449	- 0.1177	- 0.8193
Ratio	-0.0001	- 1.7806	- 8.13E-05	- 1.6382	- 0.0001	- 1.7622
$D_{max,t}$	0.1219	26.6404*	0.1275	30.6587*	0.1227	24.3783*
$D_{min,t}$	-0.1160	- 6.7061*	- 0.1061	- 5.1494*	- 0.1173	- 6.5957*
Tm_t			0.0006	1.4306		
$D_{Tmax,t}$			0.0140	2.8519*		
$D_{Tmin,t}$			0.0303	4.8920*		
RR_t			0.0005	0.7185		
$D_{RR\ max,t}$			- 0.0214	- 1.7448		
$D_{RR\ min,t}$			0.0065	1.6109		
Tm^E_t					0.0002	0.3404
$D^E_{Tmax,t}$					0.0028	0.3548
$D^E_{Tmin,t}$					0.0026	0.3580

Panel B

	Equation 1	Equation 2	Equation 3
R-squared	0.4380	0.5123	0.4400
Adjusted R-squared	0.4150	0.4781	0.4090
AIC	- 4.4243	- 4.5134	- 4.4018
SC	- 4.2749	- 4.2747	- 4.2075

Figure 1: Comparison of Spot and Future prices across different European markets.

Sample period from 24th October 2004 to 21st March 2006. This figure shows the trend of CO_2 prices from the beginning of each market. The figure A (B) shows the spot (futures) price of CO_2 European Allowances. The vertical lines indicate the period of the study. Source: EEX, Powernext, Nord Pool, ECX and own elaboration.

Figure 1-A. Spot Prices of CO_2 Allowances.

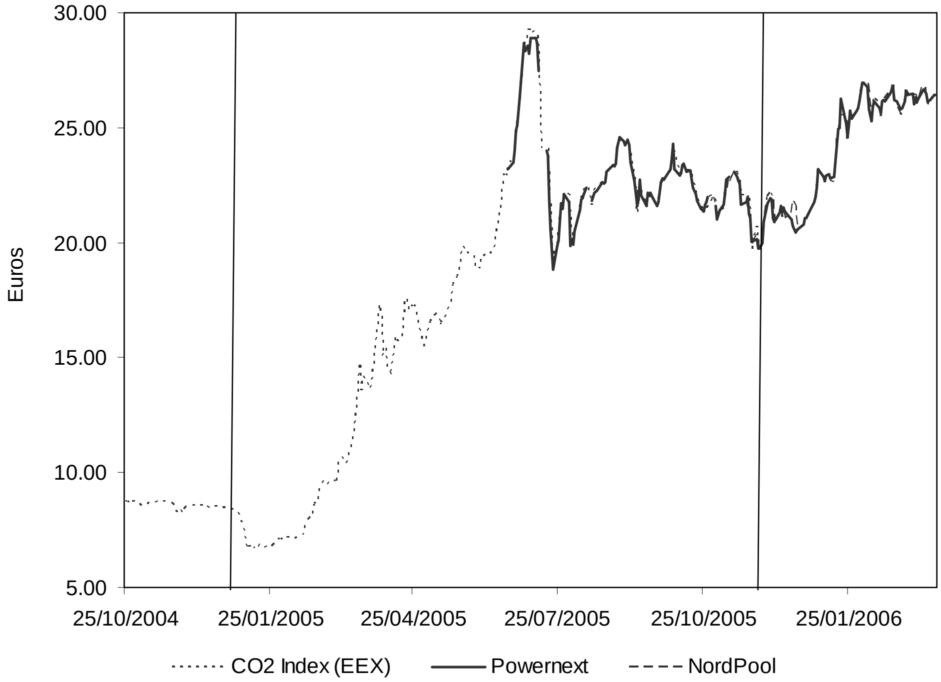
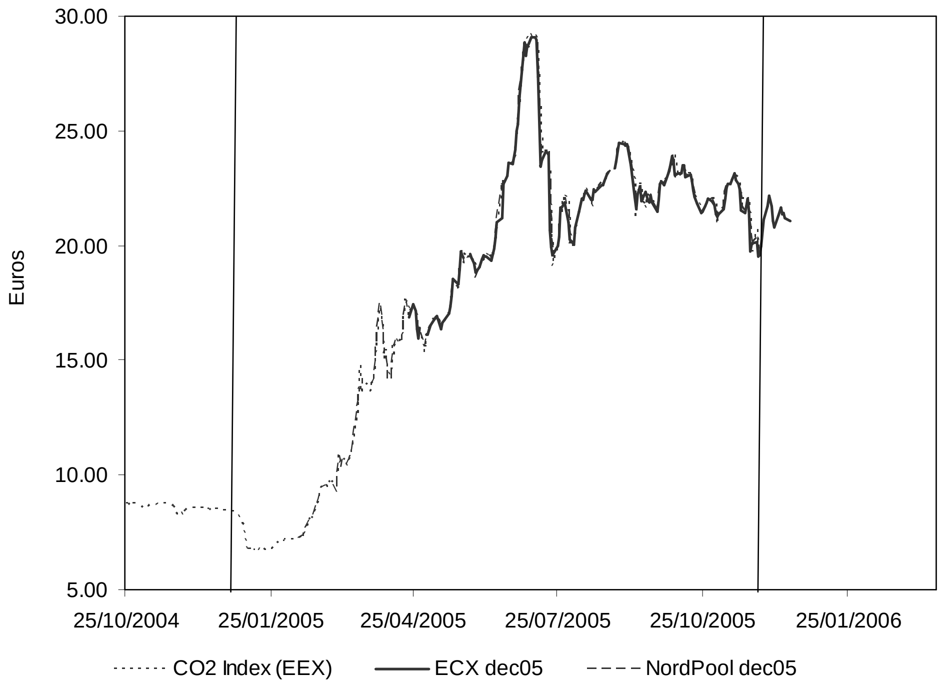


Figure 1-B. Future Prices of CO_2 Allowances with maturity in December 2005.



Annex 1: Augmented Dickey-Fuller Tests.

Augmented Dickey-Fuller (ADF) Tests used both in levels and in first differences. Panel A (B) shows the ADF Tests statistics for prices (returns) series of Brent, Gas and Coal. MacKinnon (1991) critical values for rejection of hypothesis of a unit root are -2.57432218 (for 1% of confidence) and -1.94099356 (for 5% of confidence).

Panel A: ADF Test statistics for prices series

	ADF Test statistics
CO_2 Prices	0.4097
Brent Prices	0.9507
Gas Prices	1.0886
Coal Prices	-0.8807

Panel B: ADF Test statistics for returns series

	ADF Test statistics
Brent Returns	-10.5337
Gas Returns	-12.5607
Coal Returns	-11.6328
CO2 Returns	-9.0535

CHAPTER 3

The Impacts of National Allocation Plans on Carbon Markets

3.1. INTRODUCTION

Since 1 January 2005, the European Union Emission Trading Scheme has facilitated trading in a new market: the European Union Allowances (EUAs) market. In this framework, it has been possible to trade the right to emit one tonne of CO_2-equivalent (CO_2-e) in many organized markets in Europe since 11 February 2005 and thus the interest in studying the efficiency of this market in its early state. The structure of the emission markets and the legislation from the European Union that organizes the obligations of Member States leads to sporadic releases of information concerning many aspects that may have an influence on the carbon markets. Among those aspects, we find (i) news related to the National Allocation Plans, documents in which each Member State determines both the total quantity of CO_2-e allowances available and the allocation made to each installation covered by the EU ETS, and (ii) the announcements of the actual and verified emissions by the companies and Member States through the European Commission.

The release of information in carbon markets has some attractive features for both academics and traders: it is unscheduled, sporadic and numerous. The aim of this paper is to study the impact of new information on carbon prices and their volatility. To our knowledge this is the first attempt to study this issue for this new market. In the literature on Futures Markets, there are a large number of articles that apply the event study methodology to study how and when information enters the market in a huge variety of contexts. Following McKenzie et al. (2004), two event study approaches are used. The first one consists of estimating the abnormal returns as coefficients of the dummy variables that correspond to event days in a regression (see Christie-David and

Chaudhry (2000), Lusk and Schroeder (2002) and Simpson and Ramchander (2004), among others). The second approach is the Constant Mean Return model that measures the abnormal returns from a benchmark period (see Mann and Dowen (1997) and Tse and Hackard (2006), among others). In this study, we have followed these two approaches when applying statistical event study methodology using daily carbon futures returns. However, the particularities of our data series forced us to adapt the methodology to the existence of a huge amount of very closed and unscheduled announcements affecting a sole price series. In order to minimize big surprises during the prediction period when applying the Constant Mean Return model, we propose the Truncated Mean model. This approach is a modification of the Constant Mean Return model in which the abnormal returns in the estimation period are obtained using a truncated mean.

The paper is structured as follows. The next section explains in detail the types of announcements we have considered, how the release of information is produced and when it should arrive in the market. The European carbon markets are briefly described in Section 3. The different price series are presented and the correlations among them are obtained in order to select the longest and more representative series of European carbon prices. The influence of the different types of announcements on both returns and volatility are analysed in Section 4 and 5, respectively. Finally, the last section summarizes the most important findings and then concludes.

3.2. RELEASE OF INFORMATION IN THE EUROPEAN UNION EMISSION TRADING SCHEME

In the framework of the Kyoto Protocol, the European Union has set up the Emission Trading Scheme (ETS) in order to reduce greenhouse gas emissions. The European

Union Emission Trading Scheme (EU ETS) started on 1 January 2005 and is driven by the 2003/87/EC directive, amended by the directive 2004/101/EC. The objective of the reduction of emissions is scheduled by Phases (or commitments periods). The European Union has established the period 2005-2007 as Phase I. Phase II, which coincides with the first compliance period of the Kyoto Protocol, ranges from 2008 to 2012. Phase III will probably start in 2013.

Following the criteria given by the European Commission, for each Phase of the EU ETS, each Member State in the European Union has to elaborate its National Allocation Plan (NAP). The NAP is the document in which the Member State determines both the total quantity of CO_2-e allowances available in the Member State and the allocation made to each installation covered by the Scheme. The draft of this document must be published for public consultation before the Member State final version is delivered to the European Commission. Once the NAP has been notified, the European Commission has 3 months for its assessment, and the publication of the corresponding Commission Decision. It is compulsory that the European Commission approves the NAP of each European country. If it is not the case, the NAP will be modified until the European Commission approves it. All NAPs must be submitted to the European Commission by the end of the June two years before the start of the corresponding Phase, so that the final NAP can be approved at the end of that year. The procedure makes it difficult to know in advance the exact date of publication of new information. Nevertheless, on the web page of the European Commission the information about the NAPs with Commission Decisions, the notified NAPs to the Commission and the Drafts for public consultation are made public.[49] Figure 1 depicts this process graphically.

[49] See http://ec.europa.eu/environment/climat/2nd_phase_ep.htm for the detailed information.

[Please, insert Figure 1].

To supervise the achievement of the objectives, the European Commission has established that each company covered by the 2003/87/EC Directive must submit every 31 March the verified emissions of the previous year. Additionally, those companies must surrender not later than 30 April the allowances of the previous year. For example, the companies submitted 2005 verified emissions reports by 31 March 2006 and surrendered the allowances of that year no later than 30 April 2006. The Commission Independent Transaction Log (CITL) informs punctually about the exact day of publication of the compliance of the majority of the companies covered by the 2003/87/EC Directive. When this information is published the agents in the market know whether the companies are long or short in respect of the allowances that they have received for free from their governments. Additionally, around 15 May, the Members States must submit a report of the verified emission to the European Commission including all the companies in the country covered by the European Directive. All those reports are also made public through the CITL.

Specifically, the different types of announcements have been divided into two categories: news strictly related to National Allocation Plans (NAPs) and news related to the Verification of Emissions (VER). In the first group we have 6 categories of events: Notification of Phase I NAPs (NAPs for Phase I of the EU ETS: 2005-2007) to the European Commission (NOT1), Notification of Additional Information related to the Phase I NAPs to the European Commission (NAI1), Approval of the Phase I NAPs (A1), Notification of Phase II NAPs (NAPs for Phase II of the EU ETS: 2008-2012) to the European Commission (NOT2), Notification of Additional Information related to the Phase II NAPs to the European Commission (NAI2), and Approval of the

Phase II NAPs (A2). In the second type of events, the Verification of Emissions, there are 2 subcategories: verified emissions for the year 2005 (VER2005) and verified emissions for the year 2006 (VER2006).[50]

3.3. EUROPEAN CARBON MARKETS AND SELECTION OF DATA

There exist several organized markets in Europe where it is possible to trade EUAs. The EUAs are defined as the right to emit one tonne of CO_2-equivalent (tCO_2-e). Specifically, EUAs can be traded in spot markets such as Bluenext (Paris), Energy Exchange of Austria (EXAA, Vienna), Nord Pool (Oslo), European Energy Exchange (EEX, Leipzig), and Gestore Mercato Elettrico (GME, Roma). There is also a pan-European platform called Climex Alliance where it has been possible to trade spot contracts since July 2005. Furthermore, Nord Pool, European Climate Exchange (ECX/IPE, London) and EEX markets have listed Futures contracts with EUAs as the underlying commodity, and Bluenext will list this type of contract in the near future. Note that in all Carbon Futures Markets, there have been listed futures contracts for Phase I and Phase II of the EU ETS. Phase I is already finished and thus, at the present time it is only possible to trade Phase II futures contracts. Since 13 October 2006 the ECX also trades Options on the EUAs.[51,52] Figure 2 shows the traded volume in both spot and futures markets. The traded volume is notably higher in futures than in spot markets and the market with the highest features in volume is the ECX.

[50] See Annex 1 for the list of dates with the announcement that took place on each particular date.

[51] Additionally it has been possible to trade futures contracts of Certificate Emissions Reduction units (CERs) in Nord Pool since June 2007. A CER is a tradable unit of greenhouse gas emission reductions by a project registered under the Clean Development Mechanism of the Kyoto Protocol. Those units may also be traded in Bluenext and in ECX. It will also be possible to trade CERs through spot contracts in Bluenext in a near future.

[52] For additional information about these markets see the official web pages of the carbon markets in Europe: Bluenext (www.bluenext.eu/), CLIMEX (www.climex.com), EEX (www.eex.de), ECX/IPE (www.europeanclimateexchange.com), EXAA (www.exaa.at/cms), Nord Pool (www.nordpool.no), and GME (http://www.mercatoelettrico.org).

[Please, insert Figure 2].

It must be pointed out that not all the carbon trading is done in organized markets. The European Energy Exchange (EEX) soon calculated an index of over-the-counter (OTC) forward carbon prices, called *CO_2 Index* or *European Carbon Index*. This index has been published and provided on each trading day from 25 October 2004 to 30 November 2005. The index is a volume-weighted average price of OTC forward trading activities of market participants with delivery until 30 April 2006. The London Energy Brokers' Association (LEBA) also created an OTC carbon index.[53] The *LEBA Carbon Index* is calculated every trading day using the volume weighted average of EUA trades transacted by LEBA member firms and takes into account all carbon deals transacted with delivery on 1 December 2007, 1 December 2008, and 1 December 2009.[54]

We have compared in Figure 3 the European *CO_2 Index* from EEX with the *LEBA Carbon Index* (Panel A), the Bluenext spot price series (Panel B) and the ECX futures contract with delivery in December 2007 (Panel C).

[Please, insert Figure 3].

As we can appreciate from Figure 3, the evolution of all price series has been really similar. Prices started around 8 €/tCO_2-e by the time the EU ETS was launched and were relatively stable until February 2005. Then the prices increased reaching a peak (29.30 €/tCO_2-e) on 7 July 2005. The prices decreased and stayed in the 20-25 €/tCO_2-e range until December 2005 when a bullish period started. Another peak was reached on

[53] The LEBA is comprised of 10 members, who provide coverage for all key product groups in the energy sector: oil, gas, power, coal and emissions.

[54] LEBA also calculates two more indices. The first one is the *LEBA 0800-1000 Carbon Index* which takes into account all carbon deals transacted with delivery on 1 December 2007, 1 December 2008 and 1 December 2009 between 8 a.m. and 10 a.m. The second one, *LEBA Carbon Index Spot*, takes into account all carbon deals transacted with delivery on spot 1 December 2006, 1 December 2007 and 1 December 2008. Please see http://www.leba.org.uk for more information on the LEBA members and index.

18 April 2006 when Futures prices with delivery December 2007 were above 30 €/tCO_2-e. Successive decreases brought the carbon prices to the range 15-20 €/tCO_2-e. On 21 September 2006 a decreasing price trend started that would not stop until the end of the sample (18 May 2007). On 7 November 2006 prices definitively broke the 10 €/tCO_2 barrier and on 19 July 2007 reached the barrier of 1 €/tCO_2 for the first time. The prices were at 0.28 €/tCO_2 on 18 May 2007, the end of the sample period.

The similar trend between figures can also be confirmed with a cross correlation analysis in prices (Panel A of Table 1) and returns (Panel B of Table 1).[55]

[Please, insert Table 1].

All the contemporary correlation coefficients are statistically significant at the 5% level. The positive and significant correlation coefficients indicate that all markets are strongly correlated and all of them incorporate the information in a very similar way.[56] We find the same results when comparing the future contracts that continued being traded after 30 November 2005.

To analyse the influence of NAPs related announcements on carbon prices, we are interested in the most representative series of EUA prices. Taking into account the above mentioned findings, we have chosen the forward price of the *CO_2 Index* traded in the European Energy Exchange (EEX), from 25 October 2004 to the expiry of the contract (30 November 2005).[57] This was the longest reference price for the European carbon market during the first year of the EU ETS and, as showed before, it was highly

[55] As we justify in Section 4, the returns have been defined as $r_t=ln(P_t/P_{t-1})$, where P_t is the price series at time t.
[56] Since in the EXAA market the trading takes place only once a week, it has been eliminated from the correlations of prices and returns as the number of observations is very small. Climex Aliance and GME have also not been included since not enough data is available.
[57] The data was obtained directly from the EEX webpage.

correlated with the other markets both in prices and returns. From 1 December 2005 to the end of the sample (18 May 2007), we have used the European Climate Exchange (ECX) nearest futures contract data because, as we have seen in Panel B of Figure 2, it is the carbon market with the highest features of volume.[58] In this paper we study the effects of NAP announcements on Phase I futures prices. It is important to note that with the sample period considered (24 October 2005 to 18 May 2007), we have taken into account all the announcements related to the first two years of the EU ETS (2005 and 2006) as we waited until the 2006 verified emissions were made public (around 15 May 2007).

Finally, given that carbon prices are not stationary (see Figure 3 and Panel A of Table 2), they have been converted into stationary returns taking first logarithm differences. That is, we have carried out our study using continuous compounded returns constructed as $r_{c,t} = ln(P_{c,t} / P_{c,t-1})$ where $P_{c,t}$ is the carbon price at time t. Additionally, we have calculated the statistics of carbon returns. As can be appreciated in Panel B of Table 2, the normality hypothesis for the carbon returns series is rejected. The Jarque and Bera test statistic indicates that the carbon returns series is non-normally distributed. Furthermore, the series present much fatter tails than a normal distribution.

[Please, insert Table 2].

[58] Following http://www.europeanclimateexchange.com/default_flash.asp, we have construct the ECX nearest Futures contract series as follows: from 20 December to 27 March we have taken the March 2006 contract, then the June 2006 contract, the September 2006 contract and from 26 September to the end of the series, the nearest monthly contract. The data was obtained from the ECX web page.

3.4. INFLUENCE OF THE ANNOUNCEMENTS ON CARBON RETURNS

Starting from the return series constructed as above mentioned, we have applied the event study methodology to examine carbon returns behaviour around NAPs-related events. Specifically, we have used two approaches, the first one is based on a regression method and the second one is based on the Constant Mean Adjusted Return model.

3.4.1. The Regression Approach

The measurement of abnormal returns modelled as regression coefficients is based on the use of dummy variables in a regression framework to parameterize the effects of each particular event. In this case, the abnormal returns are modelled as regression coefficients and the sample includes the event period and the data before and after it. As Binder (1998) points out, this method simplifies the estimation, since the benchmark parameters and the abnormal returns are estimated in one step. Furthermore, this approach can take into account some distributional aspects such as volatility clustering, leptokurtosis or the presence of ARCH effects.

Following this methodology, we have estimated the model presented below in order to analyse the effects of the release of NAP-related information on carbon returns ($r_{C,t}$):

$$r_{C,t} = \theta' x_t + \beta E_t + \varepsilon_t$$

where the vector x_t includes a constant term and non-event related explanatory variables and E_t is the vector that includes the dummy variables representing each one of the events considered. Each event variable has ones on the announcement days and zeros otherwise.

Concerning the non-event related variables, following Mansanet-Bataller et al. (2007), we have considered the prices of energy variables. Specifically, we have chosen the most representative prices of oil, natural gas and coal in Europe. In order to take into account the series of energy variables that better fits the front futures contract of carbon explained before, we have also constructed the front contract for the energy variables. That is, we have chosen the contract for the energy variables with the closest maturity to the maturity of the carbon front contract. All series data have been taken from Reuters Database. The futures contract on Brent is quoted in US$ per barrel, the futures contract on Natural Gas is quoted in GBP per therm and the coal contract is quoted in US$ per metric tonne. To carry out the study, we have converted them into euros using the daily exchange rate data available from the European Central Bank.[59] As in the case of carbon prices, energy prices also present a unit root and they have been converted into stationary returns taking first logarithm differences in the same way as carbon prices: $r_{i,t} = ln(P_{i,t} / P_{i,t-1})$ where P_{it} is the i-th price at time t and where $i = b$ (Brent), g (Natural Gas), and cl (Coal).[60]

The dummy variables have been taken into account in two ways. In the first model, we have considered the effect of one dummy variable for each type of event described before (NAPs and VER). In the second model we have separated those two variables into eight dummy regressors (explained in Section 2) and we have estimated the regression again. For each type of event the dummy variables are constructed with ones on the days of announcements of its type and zero otherwise.

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[59] See http://www.ecb.int.

[60] See Annex 2 for the results of the Dickey – Fuller Unit Root test.

Both regressions have been estimated by applying the Newey-West covariance matrix estimator that is consistent with the presence of heteroskedasticity and autocorrelation. The results of the regressions are presented in Table 3.

[Please, insert Table 3].

As we can observe, the regression with the dummy variables disaggregated (model 2) is a better approach than the one with the dummy variables aggregated in NAPs and VER (model 1). Supporting this statement, the R^2*–Adjusted*, the *Akaike information criterion* and the *Schwarz criterion* are presented in Panel B of Table 3.[61]

Related to the dummy variables, only in the regression with the dummy variables considered separately do we find some coefficients statistically different from zero (see model 2 in Panel A). The coefficients of those variables are the Notification of Additional Information and Approval of the Phase I NAPs (NAI1 and A1, respectively). These results are coherent with the fact that only news related to the Phase I of the EU ETS affects the front futures contract which reflects the prices for the Phase I of the Scheme. The sign of the strictly NAPs events is positive. This means that news related to Phase I was considered as being restrictive and thus caused an increase in prices.

Additionally, the coefficients associated with verifications of emissions (VER2005 and VER2006), both from the Phase I of the EU ETS, are statistically different from zero. In that case the reaction of the market is different from one year to the other although the information about verified emissions in 2005 and 2006 (made public in May 2006 and April 2007, respectively) was in both cases that the companies were long on allowances.

[61] In Mansanet-Bataller et al. (2007), only the energy variables Brent and Gas lagged one period were statistically significant. In this case, with a different sample period, we find statistical significance of the coefficients of the variables Brent and Gas that are contemporaneous. It is important to note that in both cases the influence of coal is not statistically significant.

If we look thoroughly at the price series around these dates we will find that the increase of prices on the official announcement date of 2005 verified emissions (May 2006) was preceded by a huge fall. So, the price increase on the day of the verified emissions corresponds to a correction of a previous fall. However, the reaction of the market to the information related to the real emissions in 2006 (April 2007) was a decrease in the prices on the day of the announcement. As the information was that the real emissions had been reduced in the European Union, the market participants continued to trade the allowances at a lower price in order to incorporate the new information received on the announcement day.

In global terms, we can say from these results that the carbon market reacts to new information relative to Phase I. However, as we have shown, we need to know what has happened the days before the announcement in order to properly interpret the results. Furthermore, following McKenzie et al. (2004), the use of all available data could lead to spurious inferences when, as in our case, the sample does not present a normal return constant over time as we have shown in panel B of Table 2.

Besides, when studying regulatory events on carbon market, the formal date may not coincide with the date when the new information reaches the market. In this case, the use of the regression approach may have little power to reject the null hypothesis of no effect on the carbon price. For all these reasons, we have proposed the Truncated Mean model that lets that a broader range of days be analyzed.

3.4.2. The Truncated Mean Model

Following Brown and Warner (1985), in the Constant Mean Adjusted Return model approach, the abnormal returns are measured as the difference of the returns in t minus a mean return from some benchmark of the estimation period. In this paper, we have adapted the event study methodology to the particularities of our case. We have only one commodity (carbon prices) affected by a huge quantity of close and sporadic announcements. Specifically we have calculated the benchmark return as a truncated average of the estimation period. That is, in order to calculate the truncated mean return, we have excluded the 10% higher returns and the 10% lower returns of the estimation period. The objective is to try to minimize the effect of big surprises in the estimation period.

We have defined $\bar{r}_{a,\tau}$ as the truncated mean for the announcement day *"a"* and for the *2*l* days around it (*l* is the number of days in the prediction period before the announcement, which coincides with the number of days after it). In order to calculate this truncated mean we proceed as follows:

1. We consider the announcement day as the reference day ($t = 0$).
2. We define the estimation period as the days included in the interval from $t_1 = -(\tau + l)$ to $t_2 = -(l + 1)$. We have considered τ = 10, 20 y 30. Therefore, following Milonas (1987) the estimation periods have effectively τ days and finish *l+1* days before the announcement.
3. We reorder the τ returns of the estimation period from the smallest to the largest one such that r_1 is the smallest return in the estimation period and r_τ the largest one with $\tau = 10$, 20 and 30 respectively.
4. We define *k* as the number representing 10% of the estimation period and consequently it is the number of returns that will be excluded from each of

the extremes: $k = \tau * p$ where τ is the number of days in the estimation period and p = 10%.[62]

Given that *k* is an integer, following Wilcox (2001) we have obtained the truncated mean as:

$$\bar{r}_{a,\tau} = \frac{1}{n-2k}\sum_{i=k+1}^{n-k} r_i$$

Note that r_i is the i^{th} return of the estimation period after they have been ascending ordered.

Additionally, we have calculated for any announcement *"a"*, a standardized excess return $ZR_{a,t}$ for each day of the prediction period.[63] The standardized excess returns are the excess returns standardized by the truncated standard deviation in the estimation period, calculated following the same procedure as in the mean case. The expression for the standardized excess returns is:

$$ZR_{a,\tau,t} = \frac{r_{a,t} - \bar{r}_{a,\tau}}{\sigma_a}$$

We then calculate, for each of the *(2*l+1)* days of the prediction period, the portfolio standardized excess returns, which is an equally weighted portfolio of the standardized excess returns:

$$\overline{ZR}_{a,\tau,t} = \frac{1}{N}\sum_{n=1}^{N} ZR_{a,\tau,t}$$

[62] Note that *k* is 1, 2 and 3 in the case of an estimation period of 10, 20 and 30 days, respectively.

[63] The prediction period has *(2*l + 1)* days.

where N is the number of announcements of a specific type of event. The null hypothesis is to test whether the portfolio excess returns are equal to zero on the day of the announcement ($t = 0$).

We have considered three different scenarios and we have performed the test in all of them. The first one takes into account all the announcements produced in the sample period and the results for the variables grouped in NAPs and VER are shown in Panel A of Table 4. The second scenario considers only the announcements that do not have another announcement in the three previous days. These results are presented in Panel B of Table 4. Finally, the third scenario is limited to the announcements where no other announcement has been produced in the six days surrounding it. These results are presented in Panel C of Table 4. Additionally, we have performed the same analysis substituting the returns series by the residual series of the regression of carbon returns taking as independent variables the energy variables of the previous section.[64] The results are also presented in Panels A, B and C of Table 4.[65]

[Please, insert Table 4].

As can be appreciated in Table 4, there are many events in which there are statistically significant differences before the announcement date. This occurs when we consider the complete sample (Panel A) and when we take into account the other two scenarios (Panel B and C). Additionally, most of the returns on announcement days present statistical significance which means that the new information has an effect on the price series when it is formally issued. As to what concerns the statistical significance after

[64] The specification of the regression is $r_{c,t} = \alpha + \beta_1 r_{b,t} + \beta_2 r_{g,t} + \beta_3 r_{cl,t} + \varepsilon_t$.

[65] We only present the results with the returns (resiuals) standardized with the truncated mean and variance of the estimation period of 10 days. The results of the standardized returns with the truncated mean and variance of the estimation period of 20 and 30 days are similar and they are available upon request.

the announcement day, we should only focus on Panel C of Table 4 as it is the only one not affected by other announcements dates in the prediction period.

In order to study in depth which type of announcement is relevant to the market, we have performed the analysis with the events considered separately in eight subcategories. The results for the most restrictive scenario, the one considering only the announcements without any other announcement in the six days surrounding it, are presented in Table 5.[66]

[Please, insert Table 5].

In Table 5 we can observe two types of reactions to news. In the case of Phase I related news (NAI1 and A1), we find significant and positive reaction while in the case of Phase II related news (NAI2) significant and negative reaction is documented. The positive sign of the influence of Phase I of the EU ETS events (NAI1 and A1) on carbon Phase I front futures contract prices may be interpreted as the market perceiving a future shortage of EUAs when the announcement is released. On the other hand, the events concerning Phase II of the EU ETS are issued once the market perceives that the allocations of EUAs for Phase I of the EU ETS could have been too generous. Consequently, the negative sign of NAI2 influence on carbon Phase I front futures contract prices may be interpreted as the market reacting to the intention of the European Commission to create a bigger shortage for Phase II. That is, the market interprets that the European Commission still considers that the distribution of allowances in Phase I had been too generous. Therefore the information concerning Phase II is interpreted as new information related to Phase I.

[66] Note that there is neither NOT1 nor VER2006. The reason is that there are no announcement days without an announcement on the 6 days around the announcement for those particular events. The test has been also performed for the rest of scenarios. The results are not included for sake of brevity but are available upon request.

Additionally, we find a significant and positive influence of the 2005 Verified Emissions. In the first year of EU ETS the information that the countries had emitted fewer emissions than the allocations distributed was leaked in advance (see EFET (2006) and Arvanitakis (2006)) and the increase of prices on the announcement day must be interpreted as a correction of the precedent fall (day $t = -1$).

Related to when the information reaches the market when considering the variables separately, we always find a statistically significant price reaction the day of the announcement with the exception of the Approval of Phase II NAPs (A2). These results are coherent with what we would expect. The information of a new announcement related to Phase I is relevant for the market agents trading Phase I allowances. Additionally, in many cases there is also a significant reaction on some of the days before the announcement. This means that the arrival of information occurs before the official announcement day. Note that the direction of the price reaction is the same as on the announcement day.

Panel B of Table 5 presents the results when the residuals series are considered. In this case the findings confirm that the market reacts before or on the day of the official announcement. Only Notification of Additional Information for Phase II has a significant effect on the day $t = 1$.

3.5. INFLUENCE OF THE ANNOUNCEMENTS ON CARBON VOLATILITY

Finally, we have tested whether the announcements have an influence on the carbon returns volatility. For doing so, we have performed two different tests. Firstly, by applying the Brown-Forsythe test we have tested the equality of variances of carbon returns before and after the announcement. Secondly, we have performed a sign test in which we compare the variance of the carbon standardized returns before and after the announcement. Additionally, as in the previous section when we analysed the influence of the announcements on carbon returns, we have also performed those two tests using the residual series of the regression of the carbon returns taking as independent variables the energy returns.

3.5.1. Brown and Forsythe Test

The Brown-Forsythe test allows testing for seasonality in the unconditional variance. The Brown-Forsythe test statistic is computed as

$$F = \frac{\sum_{j=1}^{J} n_j \left(\overline{D}_{\cdot j} - \overline{D}_{\cdot\cdot}\right)^2}{\sum_{j=1}^{J}\sum_{t=1}^{n_j} \left(D_{tj} - D_{\cdot j}\right)^2} \frac{(N-J)}{(J-1)}$$

where $D_{tj} = \left| r_{tj} - \hat{M}_{\cdot j} \right|$; r_{tj} is the return for the day *t* and the interval *j*; $\hat{M}_{\cdot j}$ is the sample median return for the interval *j* over the relevant n_j days; $\overline{D}_{\cdot j} = \sum_{t=1}^{n_j} \left(\frac{D_{tj}}{n_j} \right)$ is the mean absolute deviation from the median $\hat{M}_{\cdot j}$ for the time interval *j*; and $D_{\cdot\cdot} = \sum_{j=1}^{J}\sum_{t=1}^{n_j} \left(\frac{D_{jt}}{N} \right)$ is the grand mean where $N = \sum_{j=1}^{J} n_j$. The test statistic is distributed $F_{J-1,N-J}$ under the null hypothesis of equality of variances across the *J* time intervals.

Due to the particularities of our sample described before, applying this test is coherent with the idea of minimizing the effects of big surprises in the estimation period. Specifically, we have considered a prediction period of 10 days and we have separated it into two sub-periods, both of 5 days. The first sub-period consists of the 5 days preceding the announcement and the second sub-period includes the announcement day and the 4 next days. Therefore, the division of the prediction period is the announcement day. We present the results of the Brown-Forsythe test applied to the announcement days without any other announcement on the 6 days around it in Panels A and B of Table 6. The reason for that sample choice is twofold. Firstly, following this criteria we are consistent with the more restrictive analysis of the impact of the announcements on carbon returns presented in the previous section. Secondly, if we try to be more restrictive by performing the test to the announcement days without any other announcement on the prediction period considered, the sample will be drastically reduced. Additionally as presented before, the Brown-Forsythe test uses the mean absolute deviation from the median and thus the possible extreme values provoked by an announcement in the prediction period will not distort the results.

[Please, insert Table 6].

As we can appreciate in Panel A and B of Table 6, the results for the Brown-Forsythe test considering the return series or the residual series are very similar. If we consider the variables grouped in NAPs and VER (Panel A), in both cases the null hypothesis is only rejected for NAPs 10% of the time. Furthermore, in these cases, the variance is higher after the announcement.

If we have a look to Panel B of Table 6, where the events are considered separately, we can observe that only the Notification of Additional Information of Phase II NAPs provoke an increase of the variance of carbon returns 20% of the time. The remaining 80% and the rest of the announcements do not provoke any change in carbon variance. If we consider the residuals series there is an increase in the percentage of times the null hypothesis is rejected for the Notification of Additional Information related to Phase I

(NAI1) and for the Approval of Phase I NAPs (A1). In all cases the volatility increases after the announcement. Finally, in no case is the null hypothesis rejected when considering the announcements related to verification of emissions (VER).

Overall, even if, when the variance before and after the announcement is statistically different, an increase of the variance is detected after the announcement, in the majority of cases the variance before and after the announcement is not statistically different (all percentages of rejection are below 35% and most of them are 0%). The results obtained are then coherent with the idea that NAPs-related announcements do not have an important effect on carbon volatility.

3.5.2. Sign Test of Carbon Variance

Following Milonas (1987), we have performed the equality test of the variance of the standardized excess returns in order to complete the analysis of the equality of the variance before and after the announcement. Following the research line of the preceding sections, we have also applied this test to the residuals series. Specifically, we have separated the period comprised of the 5 previous days to the announcement from the period comprised of the day of the announcement and the next 4 consecutive days. That is, we have considered the standardized returns explained in the Truncated Mean Model section with $l = 5$ and we have compared the variance of those two sub-periods. As in the case of the Brown-Forsythe test and for the same reasons, we have considered the sample period of the announcements without any other announcements on the 6 days surrounding it.

The null hypothesis of the sign test is that the variance of the standardized returns (residuals) during the five days preceding the announcement of a particular event is equal to the variance of the standardized returns (residuals) in the period starting from the announcement day and finishing 4 days after. We represent this as follows:

$$H_0 : \sigma_0^2 = \sigma_1^2 \qquad or \qquad H_0 : \theta = P(X > \sigma_0^2) = P(X < \sigma_1^2) = 0.5$$

That is, if the sample data for each type of event is consistent with the hypothesized variance value for this particular event, half of the sample observations related to the event will lie above σ_0^2 and half below. Thus the number of observations larger than *K* can be used to test the validity of the null hypothesis. The two possible alternative hypotheses are:

$$H_1 : \sigma_0^2 > \sigma_1^2 \qquad and \qquad H_1 : \sigma_1^2 > \sigma_0^2$$

As the distribution of the random variable *K* is the binomial probability with parameters *N* and θ, with $\theta = 0.5$, the rejection region for the $H_1 : \sigma_0^2 > \sigma_1^2$ for an α-level test is:

$$K \in R \qquad for \qquad K \leq k_\alpha'$$

where k_α' is chosen to be the largest integer which satisfies:

$$P(K \geq k_\alpha' | H_0) = \sum_{i=k_\alpha}^{N} \binom{N}{i} (0.5)^N \leq \alpha$$

where *N* is the number of announcements of a particular event.

For $H_1 : \sigma_1^2 > \sigma_0^2$, the rejection region for an α-level test is:

$$K \in R \qquad for \qquad K \geq k_\alpha$$

where k_α is chosen to be the smallest integer which satisfies:

$$P(K \geq k_\alpha \mid H_0) = \sum_{i=k_\alpha}^{N} \binom{N}{i} (0.5)^N \leq \alpha$$

The results of the one-side tests for the events considered grouped are shown in Panel C of Table 6 and the results of the test for the events considered separately in Panel D of Table 6.[67] In both cases the p-value is presented for the two possible alternative hypotheses.

As shown in Panels C and D of Table 6, for most of the events, the carbon returns present the same variances before and after the event. Only in the case of NAPs (Panel C) and in the case of Notification of Additional Information for Phase II NAPs (NAI2 in Panel D) do the returns show higher variance after the event (p-values<0.05). In the case of the residuals series it is not possible to reject the null hypothesis and consequently we cannot reject the equality of variances of residual series before and after the announcement. The results of the tests are the same for all types of events independent of whether we consider the variables grouped together or separately. These results are in line with the results obtained with the previous test and indicate a weak effect of announcements on carbon volatility.

3.6. SUMMARY AND CONCLUDING REMARKS

In this article we analyze the effects of new information on carbon prices. Given that we have a lot of close and sporadic announcements that affect a sole price series, we have adapted the Event Study methodology to our particular case and we have proposed a

[67] In this case the returns and residuals are standardized with the truncated mean and variance of a period of 10 days.

redefinition of the Mean Return Model methodology that we have named as the Truncated Mean model.

Concerning the effects of NAPs announcements on carbon returns, we find that both Phase I and Phase II announcements have an influence on carbon returns on the day of the announcement and in a few cases on the following days. Surprisingly, we have also detected significant returns on days previous to the official announcement. Related to the variations in the volatility of carbon returns, we have not observed differences before and after the announcement. Both the presence of significant abnormal returns up to three days previous to a NAP-related event and the absence of volatility effects when the official information is revealed, suggest that there has been a leakage of information before the announcement.

These findings support the request made by the European Federation of Energy Traders (EFET, 2006) to the European Commission as a consequence of the release of real emissions data for 2005. Specifically EFET asked for carbon price sensitive information that was *accurate, final and published in such a way as to be available to all market participants at the same time.*

Table 1: Cross Correlation Coefficients.

This Table presents a cross correlation analysis in prices (Panel A) and returns (Panel B). Sample period consists of data from 24 October 2005 to 15 May 2007. C_INDEX is the OTC future contracts index calculated by EEX, LEBA_1 refers to the LEBA carbon index for prices of the first phase of the EU ETS, BN_S is the spot prices in Bluenext. ECX_FC1 refers to the front future prices in ECX for the first phase of the EU ETS, and ECX_FC2 to the front future prices in ECX for the second phase of the EU ETS. The critical value for the statistical significance of the correlation coefficient is calculated as $2/n^{1/2}$. All the coefficients are statistically significant at the 5% level.

Panel A: Correlations in Prices

	LEBA_1	BN_S	ECX_FC1	ECX_FC2
C_INDEX	0.9978	0.9749	0.9902	0.9220
LEBA_1	1.0000	0.9991	0.9990	0.7993
BN_S		1.0000	0.9990	0.8115
ECX_FC1			1.0000	0.7960
ECX_FC2				1.0000

Panel B: Correlations in Returns

	RLEBA_1	RBN_S	RECX_FC1	RECX_FC2
RC_INDEX	0.8988	0.7146	0.6849	0.6177
RLEBA_1	1.0000	0.8697	0.7988	0.4568
RBN_S		1.0000	0.8193	0.4595
RECX_FC1			1.0000	0.5854
ECX_FC2				1.0000

Table 2: Dickey Fuller Test and Statistics of Carbon Returns.

In Panel A of this table are shown the results of the Dickey –Fuller test for the carbon prices and returns. The critical values for the rejection of the null hypothesis of the existence of a unit root are -3.4336, -2.8621 and -2.5671 for 1%, 5%, and 10% significance levels respectively (MacKinnon, 1991). In Panel B the descriptive statistics for carbon returns are shown.

Panel A: ADF Test Statistics for Carbon Prices and Returns

	ADF Test
Carbon Prices	-0.7468
Carbon Returns	-17.5700

Panel B: Descriptive Statistics of Carbon Returns

	r_c
Mean	- 0.005338
Median	0.000000
Standard Deviation	0.057509
Skewness	-0.569121
Kurtosis	19.47915
Jarque-Bera	7401.276

Table 3: Regression Model Results.

Panel A presents the estimates of Model (1) and Model (2). In Model (1) the regression of CO_2 returns has been calculated on energy variables and dummy variables considered grouped. In Model (2) the regression of CO_2 returns has been calculated on energy variables and dummy variables considered separately. $r_{b,t}$ are the Brent returns, $r_{g,t}$ are the gas returns, and $r_{cl,t}$ are the coal returns. The Dummy variables correspond to the Notification of the NAP for the Phase I of the EU ETS (NOT1), Notification of additional Information of the Phase I National Allocation Plans (NAI1), Approval of the Phase I National Allocation Plans (A1), Notification of the National Allocation Plans for the Phase II of the EU ETS (NOT2), Notification of Additional Information of the Phase II National Allocation Plans (NAI2), Approval of the Phase II National Allocation Plans (A2), Verification of first year real emissions (VER2005), and Verification of second year real emissions (VER2006). VER groups the last two categories of announcements and NAPs groups the first six. Panel B reports the R^2, the Adjusted R^2, the Akaike Information Critera (AIC) and the Schwarz Criteria (SC). * denotes statistical significance at 1%.

Panel A: Estimates of Model 1 and Model 2

	Model 1		Model 2	
Variable	*Coefficient*	*t-statistic*	*Coefficient*	*t-statistic*
α_1	-0.0052	-1.9570	-0.0057	-2.1574
$r_{b,t}$	0.2324*	2.1927	0.2956*	2.5082
$r_{g,t}$	0.1417*	3.6664	0.1237*	3.5350
$r_{cl,t}$	0.1203	1.1223	0.0910	0.8123
$NAPs_t$	-0.0034	-0.5059		
VER_t	0.0445	0.2061		
$NOT1_t$			-0.0042	-1.0958
$NAI1_t$			0.0138*	2.4397
$A1_t$			0.0379*	2.8483
$NOT2_t$			0.0023	0.4314
$NAI2_t$			-0.0101	-0.8680
$A2_t$			-0.0322	-1.1545
$VER2005_t$			0.5111*	102.79
$VER2006_t$			-0.1720*	-9.1981

Panel B: Goodness of Fit Measures

	Model 1	Model 2
R^2 squared	0.0232	0.1918
R^2-Adjusted	0.0232	0.1778
Akaike criterion	-2.8880	-3.0513
Schwarz criterion	-2.8468	-2.9688

Table 4: Truncated Mean Model Results.

In this Table we present the results of the test which null hypothesis is that the portfolio excess return are equal to zero. In our case we perform this test for the day of the announcement, the 3 previous days and the 3 next days. In Panel A we present the results with the complete sample. In Panel B we consider the announcements days where there has not been an announcement within the 3 previous days. Finally in Panel C we consider the announcements days where there has not been an announcement within the 6 days around the announcement. The first column in the Table presents the days ("0" is the announcement day). The next four columns refer to the standardized returns and the last 4 columns to the standardized residuals of the model 1 in the previous Table regression. The ZR_t mean column shows the mean of the portfolio of the standardized returns (residuals) for each of the event groups (NAPs and VER), and the p-value column shows the p-value of the test. NAPs include the information of the Notification, Notification Additional Info and Approval related to Phase I NAPs and Notification, Notification Additional Info and Approval related to Phase II NAPs. VER groups the Verification Emissions 2005 and Verification Emissions 2006. Number refers to the number of times an announcement of each kind event has been produced. * denotes statistical significance at the 1% level.

Panel A: All announcements considered.

	Returns				Residuals			
	NAPs		Verifications		NAPs		VER	
Days	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value
-3	-0.44038	0.0003*	4.1946	0.0000*	-0.2530	0.0383*	3.9320	0.0000*
-2	0.0187	0.8783	1.9790	0.0006*	0.0902	0.4601	1.8875	0.0010*
-1	0.0190	0.8764	-3.7270	0.0000*	-0.1104	0.3661	-3.6985	0.0000*
0	-0.0559	0.6470	-3.2116	0.0000*	-0.1567	0.1994	-3.1870	0.0000*
1	-0.0515	0.6732	-1.9181	0.0008*	-0.0129	0.9156	-1.7936	0.0018*
2	-0.1404	0.2503	-0.5483	0.3422	-0.1227	0.3152	-0.2891	0.6165
3	-0.2232	0.0677	0.3160	0.5841	-0.2285	0.0614	0.5469	0.3434
Number		67		3		67		3

Panel B: Announcements without any other announcement 3 days before.

	Returns				Residuals			
	NAPs		Verifications		NAPs		VER	
Days	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value
-3	0.1267	0.4408	4.2468	0.0000*	-0.0242	0.8825	3.9170	0.0000*
-2	-0.4659	0.0046*	3.3831	0.0000*	-0.1080	0.5110	3.1571	0.0000*
-1	0.8323	0.0000*	-1.6578	0.0190*	-0.0254	0.8768	-1.4859	0.0356*
0	0.4421	0.0071*	-2.6272	0.0002*	0.2075	0.2067	-2.6448	0.0001*
1	1.2721	0.0000*	-2.1916	0.0019*	1.2691	0.0000*	-2.0996	0.0029*
2	0.9995	0.0000*	-0.7089	0.3160	0.8553	0.0000*	-0.5282	0.4550
3	0.1846	0.2612	0.3889	0.5822	-0.0911	0.5794	0.6147	0.3846
Number		37		2		37		2

Panel C: Announcements without any other announcement during 3 days on either side.

	Returns				Residuals			
	NAPs		Verifications		NAPs		VER	
Days	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value
-3	-0.0467	0.8305	1.5596	0.1188	-0.0106	0.9612	1.5395	0.1236
-2	0.4285	0.0495*	0.6177	0.5367	0.8502	0.0001*	0.5570	0.5774
-1	0.5334	0.0145*	-2.4222	0.0154*	0.3625	0.0966	-2.3449	0.0190*
0	0.3248	0.1365	5.7114	0.0000*	1.5796	0.0000*	5.6770	0.0000*
1	-0.3220	0.1399	1.5937	0.1109	0.8367	0.0001*	1.4365	0.1508
2	0.0868	0.6907	0.2513	0.8015	0.4997	0.0220*	0.3039	0.7611
3	-0.1239	0.5700	0.8095	0.4181	-0.3761	0.0847	0.6932	0.4881
Number		21		1		21		1

Table 5: Truncated Mean Model Results. Events Separated.

In this Table we present the results of the test in which the null hypothesis is that the portfolio excess return is equal to zero, for the scenario most restrictive (considering the announcement day without any other announcement on the six days surrounding it). In our case we perform this test for the day of the announcement, the 3 previous days and the next 3 days. The first column in the Table presents the days ("0" is the announcement day). The next two columns refer to the Notification of Additional Information for Phase I NAPs (NAI1). The next two columns refer to the Approval of Phase I NAPs (A1). The next two columns refer to the Notification of Phase II NAPs (NOT2). The next two columns refer to the Notification of Additional Information for Phase II NAPs (NAI2). The next two columns refer to the Approval of Phase II NAPs (A2). Finally the last two columns refer to the Verification of real emissions for the year 2005 (VER2005). Panel A (B) present the results for the returns (residuals of the regression of Model 1 in Table III) taking into account exclusively the announcements without any other announcement 3 days before and after it. In all cases the ZR mean column shows the mean of the portfolio of the standardized returns for each of the events considered, and the p-value column shows the p-value of the test. Note that there is neither Notification of Phase I NAPs (NOT1) nor Verification of real emissions for 2006 (VER2006). The reason is that there are no

Panel A: Results with the Returns series

	NAI1		A1		NOT2		NAI2		A2		VER2005	
Days	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value
-3	1.1438	0.0105*	-0.0193	0.9782	-0.6965	0.1636	-1.5122	0.0007*	0.0069	0.9865	1.5596	0.1188
-2	1.2276	0.0061*	2.1382	0.0025*	-0.3588	0.473	-0.0634	0.8873	0.3356	0.411	0.6177	0.5368
-1	0.2305	0.6062	2.3799	0.0008*	0.8891	0.0754	-0.0425	0.9244	0.5182	0.2043	-2.4223	0.0154*
0	1.4238	0.0015*	5.9898	0.0000*	-0.6682	0.1814	-2.532	0.0000*	0.2106	0.6059	5.7115	0.0000*
1	0.3552	0.4271	1.9776	0.0052*	-0.5377	0.2822	-2.3189	0.0000*	0.6623	0.1047	1.5938	0.111
2	1.6802	0.0002*	0.2664	0.7063	-0.255	0.61	-0.9746	0.0293*	-0.3351	0.4117	0.2514	0.8015
3	0.0697	0.8761	-1.1885	0.0928	-0.177	0.7233	-0.303	0.4981	0.2101	0.6069	0.8096	0.4182
Number		5		2		4		5		6		1

Panel B: Results with the Residuals series

	NAI1		A1		NOT2		NAI2		A2		VER2005	
Days	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value	ZRt mean	p-value
-3	0.5728	0.2002	-1.7318	0.0143*	-0.7593	0.1288	-1.5283	0.0006*	0.001	0.998	1.5396	0.1237
-2	1.0705	0.0167*	-0.4315	0.5417	-0.5172	0.3009	0.0831	0.8526	0.2252	0.5812	0.5571	0.5775
-1	-0.1754	0.6948	1.1579	0.1015	-0.3795	0.4479	0.2113	0.6366	0.4177	0.3062	-2.3449	0.0190*
0	1.067	0.0170*	3.9272	0.0000*	-0.5898	0.2381	-2.5841	0.0000*	0.186	0.6487	5.677	0.0000*
1	0.8216	0.0662	0.2502	0.7235	0.1454	0.7713	-2.1474	0.0000*	0.6599	0.106	1.4365	0.1508
2	0.8024	0.0728	-0.0713	0.9197	-0.3454	0.4898	-0.1332	0.7657	-0.4624	0.2573	0.304	0.7611
3	0.057	0.8986	-0.9294	0.1887	-1.4746	0.0032*	0.1143	0.7983	0.0892	0.8271	0.6933	0.4881
Number		5		2		4		5		6		1

Table 6: Equality Test Results.

This Table presents the results of two equality tests. Panel A (B) shows the results of the Brown- Forsythe test for the carbon returns and the residuals series considered grouped (separated). Panel C (D) shows the p-value for the standardized returns and residual series sign test for the variables considered grouped (separated). In all cases, the null hypothesis is that the variance during the 5 days preceding the announcement day is equal to the variance in the period made up of the announcement day and the next 4 days. In Panel A and B, the times the null hypothesis is rejected expressed in percentage. The different rows present the results for the possible alternative hypothesis. The last row shows the total of announcements of each type of event. In order to be consistent with the previous analysis, the announcement days considered are those without any announcement on the 6 days around it. For both Panel C and D, the series are standardized with the truncated mean and variance of a period of 10 days. NOT1 and NOT2 refer to Notification to the European Commission of the National Allocation Plans (NAP) Phase I and Phase II respectively, NAI1 and NAI2 refer to the Notification of Additional Information to the European Commission about the NAP Phase I and Phase II respectively, A1 and A2 refer to the Approval by the European Commission of the NAP Phase I and the NAP Phase II respectively, VER2005 and VER2006 refer to the emission verification date of the first and second year of EU ETS respectively. NAPs include NOT1, NAI1, A1, NOT2, NAI2, and A2 while VER includes VER2005 and VER2006.

Panel A: Brown-Forsythe test for events considered grouped

		Returns		*Residuals*	
Null Hypothesis	Alternative Hypothesis	NAPs	VER	NAPs	VER
$\sigma_0 = \sigma_1$	$\sigma_0 \neq \sigma_1$	10%	0%	10%	0%
$\sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	10%	0%	10%	0%
$\sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	0%	0%	0%	0%
Number of announcements =		20	1	20	1

Panel B: Brown-Forsythe test for events considered separated

Returns

Null Hypothesis	Alternative Hypothesis	NOT1	NAI1	A1	NOT2	NAI2	A2	VER2005	VER2006
$\Sigma_0 = \sigma_1$	$\sigma_0 \neq \sigma_1$	-	0%	0%	0%	20%	0%	0%	-
$\Sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	-	0%	0%	0%	20%	0%	0%	-
$\Sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	-	0%	0%	0%	0%	0%	0%	-
Number of announcements =		0	5	3	4	5	4	1	0

Residuals

Null Hypothesis	Alternative Hypothesis	NOT1	NAI1	A1	NOT2	NAI2	A2	VER2005	VER2006
$\sigma_0 = \sigma_1$	$\sigma_0 \neq \sigma_1$	-	20%	33%	0%	20%	0%	0%	-
$\sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	-	20%	33%	0%	20%	0%	0%	-
$\sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	-	0%	0%	0%	0%	0%	0%	-
Number of announcements =		0	5	3	4	5	4	1	0

Panel C: Sign test for the events considered grouped

		Returns		*Residuals*	
Null Hypothesis	Alternative Hypothesis	NAPs	VER	NAPs	VER
$\sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	0.9964	0.5000	0.9608	0.5000
$\sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	0.0133	1.0000	0.0946	1.0000

Panel D: Sign test for the events considered separately

Returns

Null Hypothesis	Alternative Hypothesis	NOT1	NAI1	A1	NOT2	NAI2	A2	VER2005	VER2006
$\sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	-	0.8125	1.0000	0.6875	1.000	0.9687	1.0000	-
$\sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	-	0.5000	0.1250	0.6875	0.0313	0.1875	0.5000	-

Residuals

Null Hypothesis	Alternative Hypothesis	NOT1	NAI1	A1	NOT2	NAI2	A2	VER2005	VER2006
$\sigma_0 = \sigma_1$	$\sigma_0 > \sigma_1$	-	0.5000	1.0000	0.9375	0.8125	0.9687	1.0000	-
$\sigma_0 = \sigma_1$	$\sigma_0 < \sigma_1$	-	0.8125	0. 1250	0.3125	0.5000	0.1875	0.5000	-

Figure 1: Deadlines of the EU ETS.

This Figure shows how the deadlines are organised in the EU ETS. Two years before the compliance period, the NAPs have to be submitted before 30 June to the European Commission. They have to be approved before 31 December of that year. When the real emissions take place two years later, the verified report has to be presented by each the companies before 31 March to their government. Before 30 April the companies must surrender the allowances that correspond to their actual emissions. On 15 May the compliance report of the Member States is published.

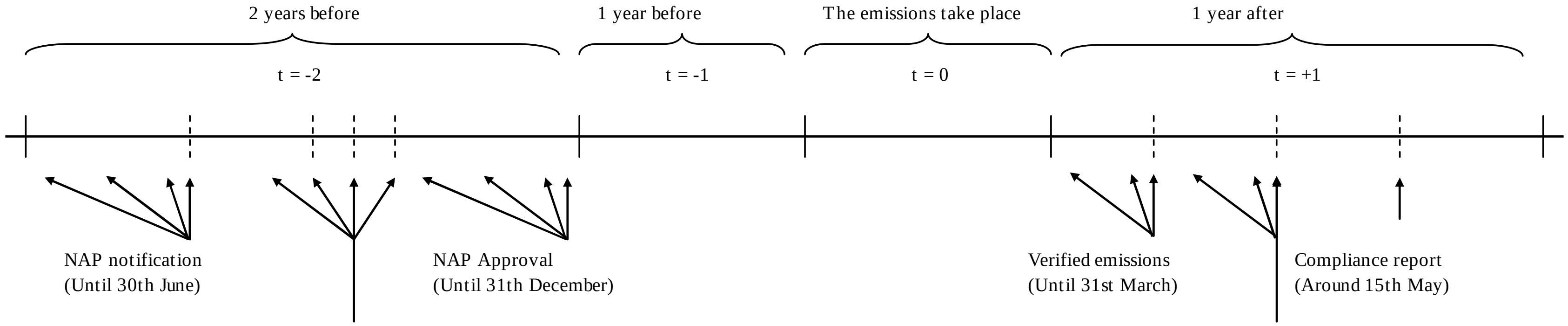


Figure 2: Volumes traded in the Carbon Markets.

In this Figure we show the volume traded in each market from its beginning to 15 May 2007. The total volume traded in the spot market has been 71 888 537 tCO_2-e and in the future market has been 870 305 000 tCO_2-e.

Figure 2-A. Percentage of Volume Traded in Spot Markets

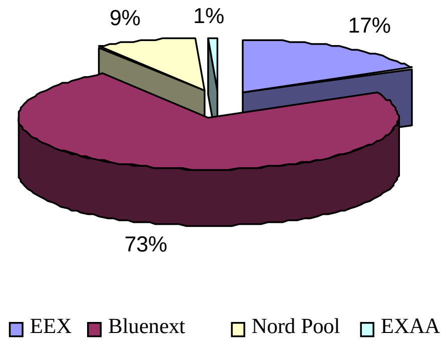


Figure 2-B. Percentage of Volume Traded in Futures Markets

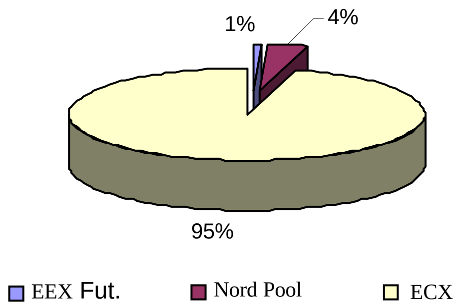


Figure 3: Comparison Different Prices across European Markets.

The sample period goes from 24 October 2004 to 15 May 2007. This Figure shows the trend of Carbon Prices from the beginning of each market. The Panel A shows the EEX Carbon Index and LEBA indexes, Panel B the EEX Carbon Index and spot prices in Bluenext and Panel C the EEX Carbon Index and the ECX December Futures contract for 2007. In these panels, once the *CO_2 Index* expires, the graphs show the OTC, the spot and the Futures prices respectively. Source: EEX, Bluenext, Nord Pool, ECX and own elaboration.

Figure 3-A. Carbon Index EEX and LEBA Carbon Index.

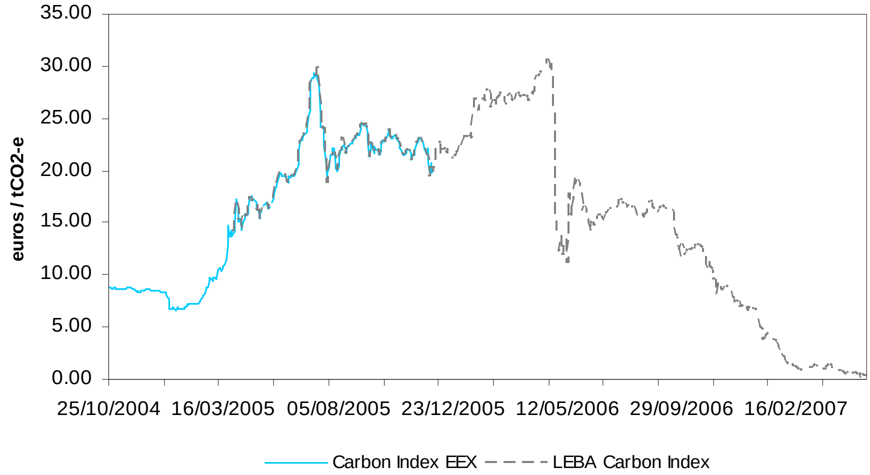


Figure 3-B. Carbon Index EEX and Blunext Spot Prices

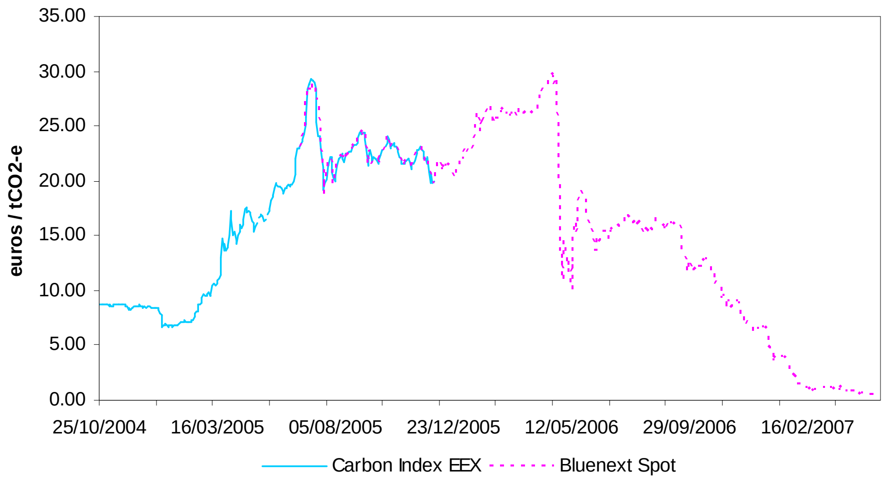
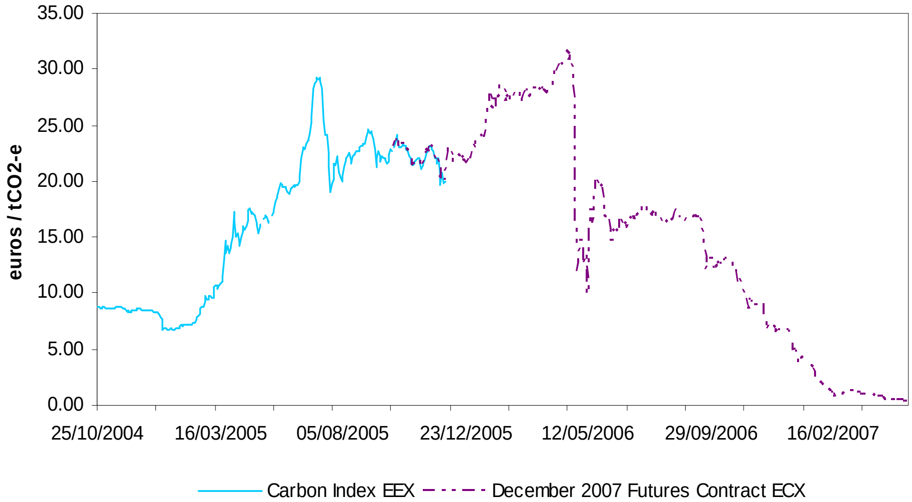


Figure 3-C. Carbon Index EEX and ECX Futures Prices



ANNEX 1: Dates of Event.

This Annex presents the dates of the announcements classified by type of event. NOT1, NAI1 and A1 refer to Notification to the European Commission of the National Allocation Plans (NAP) Phase I, Notification of Additional information to the European Commission about the NAP and to the Approval by the European Commission of the NAP all related to Phase I. NOT2, NAI2 and A2 are the same variables related to Phase II. NAPs includes all these variables. VER2005 and VER2006 refer to the emission verification dates of the first and second years of EU ETS respectively. VER includes VER2005 and VER2006. Sources: CITL web page (http://ec.europa.eu/environment/ets/welcome.do), Emission Trading web page from the European Commission (http://ec.europa.eu/environment/climat/first_phase_ep.htm), emissions market web pages (see footnote 2) and own elaboration.

		National Allocation Plans							Verifications		
DATES	EVENT	NOT 1	NAI 1	A 1	NOT 2	NAI 2	A 2	NAPs	VER2005	VER2006	VER
29/10/2004	* Notification I Aditional Information Italy		1					1			
09/11/2004	* Notification I Aditional Information Lithuania		1					1			
10/11/2004	* Notification I Aditional Information UK		1					1			
30/11/2004	* Notification I Aditional Information Spain		1					1			
01/12/2004	* Notification I Aditional Information Rep Cyprus		1					1			
03/12/2004	* Notification I Aditional Information Spain		1					1			
06/12/2004	* Notification I Aditional Information Malta		1					1			
08/12/2004	* Notification I Aditional Information Lithuania		1					1			
09/12/2004	* Notification I Aditional Information Hungary		1					1			
14/12/2004	* Notification I Aditional Information Hungary		1					1			
15/12/2004	* Notification I Aditional Information Hungary		1					1			
27/12/2004	* Approval NAPs Phase I of Republic of Cyprus, Hungary, Lithuania, Malta and Spain			1				1			
30/12/2004	* Notification Greek NAP Phase I	1						1			
03/01/2005	* Notification I Aditional Information Poland		1					1			
25/01/2005	* Notification I Aditional Information Czech Rep		1					1			
18/02/2005	* Notification I Aditional Information UK		1					1			
25/02/2005	* Notification I Aditional Information Italy		1					1			
08/03/2005	* Approval Polish NAP I			1				1			
10/03/2005	* Notification I Aditional Information Greece		1					1			
07/04/2005	* Notification I Aditional Information Czech Rep		1					1			
12/04/2005	* United Kingdom NAP Formally rejected		1					1			
12/04/2005	* Czech Rep Phase I NAP Approved			1				1			
25/04/2005	* Notification I Aditional Information Greece		1					1			
29/04/2005	* Notification I Aditional Information Italy		1					1			
16/05/2005	* Notification I Aditional Information Greece		1					1			
17/05/2005	* Notification I Aditional Information Italy		1					1			
20/05/2005	* Notification I Aditional Information Italy		1					1			
23/05/2005	* Notification I Aditional Information Italy		1					1			
25/05/2005	* Italian Phase I NAP Approved			1				1			
20/06/2005	* Greek Phase I NAP Approved			1				1			
22/02/2006	* Final UK Phase I NAP Approved			1				1			
15/05/2006	* Publication by the European Comission of the verified emissions								1		1
30/06/2006	* German Phase II NAP Notified				1			1			
07/07/2006	* Lithuanian Phase II NAP Notified				1			1			
12/07/2006	* Irish Phase II NAP Notified				1			1			
18/07/2006	* Luxembourg Phase II NAP Notified				1			1			
16/08/2006	* Latvia Phase II NAP Notified				1			1			
18/08/2006	* Slovak Phase II NAP Notified				1			1			
28/08/2006	* UK Phase II NAP Notified				1			1			
01/09/2006	* Swedish Phase II NAP Notified				1			1			
12/09/2006	* Notification II Aditional Information Lithuania					1		1			
18/09/2006	* Notification II Aditional Information Ireland					1		1			
22/09/2006	* Notification II Aditional Information Germany					1		1			
27/09/2006	* Malta Phase II NAP Notified				1			1			
28/09/2006	* The Netherlands Phase II NAP Notified				1			1			
29/09/2006	* Belgium Phase II NAP Notified				1			1			
03/10/2006	* Notification II Aditional Information UK					1		1			
13/10/2006	* Notification II Aditional Information The Netherlands					1		1			
19/10/2006	* Notification II Aditional Information Slovakia and The Netherlands					1		1			
20/10/2006	* Notification II Aditional Information Luxembourg					1		1			
02/11/2006	* Slovenia Phase II NAP Notified				1			1			
06/11/2006	* Notification II Aditional Information UK and Luxembourg					1		1			
08/11/2006	* Notification II Aditional Information Latvia					1		1			
10/11/2006	* Notification II Aditional Information Sweden					1		1			
14/11/2006	* Notification II Aditional Information Greece					1		1			
16/11/2006	* Notification II Aditional Information Latvia					1		1			
22/11/2006	* Notification II Aditional Information Lithuania					1		1			
23/11/2006	* Notification II Aditional Information Malta					1		1			
29/11/2006	* Approval NAPs Phase II of Germany, Greece, Ireland, Latvia, Lithuania, Luxembourg, Malta, Slovak Republic, Sweden, UK						1	1			
30/11/2006	* Spanish Phase II NAP Notified				1			1			
13/12/2006	* Notification II Aditional Information Belgium					1		1			
15/12/2006	* Notification II Aditional Information The Netherlands					1		1			
22/12/2006	* Notification II Aditional Information Belgium					1		1			
08/01/2007	* Notification II Aditional Information Slovenian					1		1			
16/01/2007	* Approval NAPs Phase II of Belgium and the Netherlands						1	1			
01/02/2007	* Notification II Aditional Information Spain					1		1			
05/02/2007	* Slovenia Phase II NAP Approval						1	1			
26/02/2007	* Spain Phase II NAP Approval						1	1			
26/03/2007	* Poland, France and Czech Republic Phase II NAP Approval						1	1			
02/04/2007	* Austian Phase II NAP Approval						1	1			
02/04/2007	* Publication by European Commission of 93% preliminary verified emissions									1	1
03/04/2007	* Publication of Additional Preliminary Verified Emissions									1	1
16/04/2007	* Hungarian Phase II NAP Approval						1	1			
04/05/2007	* Estonian Phase II NAP Approval						1	1			
15/05/2007	* Italian Phase II NAP Approval						1	1			
	TOTAL	1	24	6	13	19	9	72	1	2	3

ANNEX 2: Dickey – Fuller test for Energy Variables.

In this Table are shown the results of the Dickey –Fuller test for all energy series taken into account in the regression approach (Brent, Gas and Coal) in all cases for both prices and returns. The critical values for the rejection of the null hypothesis of the existence of a unit root in the series are -3.4336, -2.8621 and -2.5671 for 1%, 5% and 10% significance levels (MacKinnon, 1991).

	ADF Test
Brent Prices	-0.7468
Gas Prices	-0.9335
Coal Prices	-0.4267
Brent Returns	-17.8000
Gas Returns	-19.2863
Coal Returns	-18.6165

CHAPTER 4

CO_2 Prices and Portfolio Management

4.1. INTRODUCTION

With the objective of mitigating the effects of climate change, the European Union has launched the European Union Emission Trading Scheme (EU ETS). Under this scheme, the European large CO_2 emitting installations have restrictions on emissions and receive permits from their governments to emit tonnes of CO_2 that can be traded in several spot, futures and option markets whenever installations fulfil their emission reduction target obligations at the scheduled time. Those permits are called European Union Allowances (EUAs) and allow for the emission of one tonne of CO_2-equivalent in the European Union.

The EU ETS is organized into two phases. Phase I started in January 2005 and lasted until December 2007. Phase II of the EU ETS started in January 2008 and will last until December 2012. As banking (the transfer of allowances from Phase I to Phase II) is not allowed, there are two differentiated assets that have been traded at the same time in the European Carbon markets, Phase I and Phase II EUAs. However, since April 2008 it has only been possible to trade Phase II EUAs.

Additionally, it is important to note that the companies covered by the 2003/87/EC directive (the large CO_2 emitting installations) are not the only participants that are able to take part in the European Carbon market. Every natural and legal person is authorized to open an account and participate in emissions trading, and thus the interest in studying the existence of new investment opportunities also for those market participants that do not have emission reduction targets.

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 whether or not a portfolio is better diversified when including foreign assets (international diversification). In other cases, the authors study the diversification opportunities when introducing new assets. On one hand, 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 ability of those assets to improve the diversification of a portfolio (asset diversification). On the other hand, Jensen et al. (2002), Gorton and Rouwenhorst (2004), and Erb and Harvey (2006) analysed the impact of introducing commodities indices such as the Goldman Sachs Commodity Index (GSCI), in portfolio management.

Note that EUAs are considered in the literature (Borak et al. (2006)) as commodities. In this paper we will focus on the diversification effects of introducing EUAs in different portfolios that may or may not include commodities.

Since the interest of the investors in carbon markets is constantly increasing, jointly with the fact that Phase I of the EU ETS has just finished, the study of the effects of including those assets in a diversified portfolio is timely. The aim of this article is twofold. Hence, our first goal is to provide a description of the effects of including this new asset on portfolio diversification considering Phase I of the EU ETS. We will also analyse under what conditions the existence of this new asset (EUAs) will enlarge the investment opportunities for a European investor in Phase II of the EU ETS. To our knowledge this is the first attempt at studying the opportunity of including EUAs in a diversified portfolio. 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 we analyse whether EUAs are a desirable stand-alone investment and we discuss the possibility of considering them as a new asset class. In section 3, we present stocks, fixed income, energy, and CO_2 specific data used in the study. Then, in section 4 we will study the consequences of introducing either EUAs Phase I or Phase II in several diversified portfolios made up mainly of stock, bonds and energy commodities. Finally, section 5 presents the principal conclusions and some final remarks.

4.2. IS CO_2 A DESIRABLE STAND-ALONE INVESTMENT?

Before examining the diversification opportunities that may arise when including CO_2 assets in traditional portfolios, we will briefly examine whether it is a desirable stand alone investment. We may first ask whether this new asset is a financial asset, a new commodity, or a new asset class. In order to answer this important question, we study the characteristics of EUAs and compare them with the other known asset classes.

From the storability point of view, EUAs are similar to the traditional financial assets. The EU ETS is a market organized by accounts transactions and consequently there are no storability problems for EUAs, which are "stored", as with other financial assets, in electronic accounts. This is not actually the case for commodities. In general, commodities present storability problems that often provoke backwardation in their markets (these markets provide a hedge for producers, which may accept to sell their commodities at a futures price lower than the expectations for the future spot price and, hence, pay a risk premium). The fact that EUAs have no storability problems should avoid violent price fluctuations in spot EUA prices induced by demand and supply tensions.

However, Benz and Trück (2006) point out that while the value of a stock is based on profit expectations of the firm, this is not the case for EUA prices. In this 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, EUAs behave more similarly to commodities. This is the idea defended by Borak et al. (2006) that classed the EUAs as a new commodity that companies need, under the 2003/83/EC Directive, 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"*. Despite this, there is an important difference between operating materials and EUAs because the companies only need to have in their electronic inventories the allowances that correspond to their verified emissions for a specific year, on 30th April of the following year (2003/87/EC Directive).

Thus, while in the case of commodities the main reason for supply and demand tensions is the storability problem, in the case of EUA prices, the principal reason is the level of real emissions. As the supply of allowances is fixed in advance by the European Commission for each of the Phases, the demand for allowances is what determines the equilibrium price. Evidence of this can be seen in Figure 1 in which the evolution of Phase I and Phase II CO_2 prices are presented. The prices make reference to prices of futures contracts with maturity in December 2007 (for Phase I) and in December 2008 (for Phase II). In both cases, the information comes from contracts traded at the European Climate Exchange.[68]

[Please, insert Figure 1].

[68] As it will be shown in section 3 these prices are the most representative for Phase I and Phase II, respectively.

In this figure we can appreciate that Phase I prices tendency to zero started with the European Commission announcement on real verified emission for the year 2005 that took place on April 2006. With this announcement, it was clear to the market participants and researchers that the Phase I was over supplied and thus the price of this contract tended to zero.[69] This has not been the case for the Phase II contract whose prices oscillated in a range between 20-25 euros from the later months of 2007 until the end of the sample period (31st January 2008). Additionally, if we have a look at the market volumes of both contracts, we find that the volume of Phase II contracts has been increasing since January 2006. Note that in November 2006, the December 2008 contract was more traded than Phase I contracts. This indicates that, since November 2006, the interest of the market has focused on the Phase II of the EU ETS. Additionally, the market is constantly increasing the volume traded. The volumes of the December 2008 contract during the later months of 2007 and the first month of 2008 were rarely reached by Phase I volumes.

As has been said, another interesting issue is that most commodities present normal backwardation that becomes another factor driving commodity returns. As pointed out by Till and Eagleeye (2006), by continuously investing in front-month futures contracts one captures these returns. However, in the case of EUAs, there is a current contango market situation (Borak et al. (2006)) and thus it is not possible to increase the returns by rolling-over futures contracts.

In order to analyse the performance of EUAs, the mean, the variance, the standard deviation, the maximum, the minimum, and the Sharpe Ratio of weekly returns for both

[69] For more information, please see Mansanet-Bataller and Pardo (2008). The authors analyse the impact of official announcements made by the European Commission that have an impact on CO_2 prices.

CO_2 contracts (the one representing Phase I prices and the other representing Phase II prices) are presented in Table 1.

[Please, insert Table 1].

We can appreciate that the historical returns of the Phase I prices of the EU ETS had a very negative mean (a loss of 231.61%) and a very high standard deviation and thus a high and negative Sharpe Ratio. The high standard deviation of Phase I EUAs may be explained by the fact that at the end of the sample period considered, the price level was very low (around 0.03 euros) and small changes in the price (0.01 euros) meant a 33% decrease in prices. In Figure 2, the volatility evolution of both the CO_2 Phase I and Phase II returns is shown. Each point depicts a moving annualized standard deviation for the previous 20 prices (19 returns).

[Please, insert Figure 2].

As shown in Figure 2, the volatility is really high, particularly in the case of Phase I CO_2 returns. If we compare the evolution of the standard deviation for the returns of Phase I and Phase II, we can appreciate that the Phase II prices present lower standard deviation even if at its lowest level the standard deviation is around 25%. We obtain similar progressions if we consider the annualized standard deviations during the 5 or 10 previous weeks. However, the volatility is considerably higher as we decrease the number of previous weeks taken into account in order to obtain the annualized standard deviations.

These results suggest that investing would be very risky and with negative expected returns, and consequently is not recommended. However, this reasoning applies for a buyer. The agent that took a short position in Phase I futures contracts assumed a very high risk but obtained a very high return.

4.3. DATA

To analyse the impacts of introducing CO_2 contracts in a diversified portfolio, we are going to take into account, in addition to EUAs prices, data referring to equities, fixed income, and energy commodities. All of them, as well as the risk-free rate, have been obtained from Reuters Database.

As we are interested in determining the impact of investing in Phase I and Phase II separately and that we consider it interesting to allow for short sales, we have used in this study the front futures contract price series to represent the EU ETS Phase I prices, and the December 2008 futures contract to represent the EU ETS Phase II prices. Such a choice will allow us to compare among Phases and determine if the market opportunities have changed from one Phase to the other and if so, explain the principal reasons. The sample period runs from 22nd April 2005 to 31st January 2008. In both cases we have considered EUAs traded at the ECX given that, as we can see in Figure 3, it is the most important futures market in volume terms.

[Please, insert Figure 3]

Related to the equity and interest rate data, we have considered the most heavily traded derivatives contract in Europe, all from EUREX market. In the case of equity index derivatives contract, we have chosen futures prices on Dow Jones Euro Stoxx 50. In the case of fixed income derivatives, we have selected the three benchmarks used in Europe which are the Euro Schatz Futures (with a term of 1.75 to 2.25 years and a coupon of 6%), Euro Bolb Futures (with a term of 4.5 to 5.5 years and a coupon of 6%), and the

Euro Bund Futures (with a term of 8.5 to 10.5 years and a coupon of 6%). All these contracts are on a notional debt security of the Federal Republic of Germany.[70]

With respect to the energy prices, we have selected the most representative series in Europe. Thus, we have considered daily futures prices of Brent and Natural Gas, both traded at the International Petroleum Exchange (IPE).[71]

In order to perform our analysis and especially to obtain the Sharpe Ratio for the different assets and portfolios, we have considered the EURIBOR one month as the risk-free rate of returns.

Finally, we want to highlight two features. Firstly, for all these series of prices we have considered the front futures contracts for each asset for the sample period from 22nd April 2005 to 31st January 2008. The reason for such a choice is twofold. On the one hand, we are interested in taking into account the same type of contracts as in the case of EUAs and, on the other hand, we are considering the most liquid contract that allows the portfolio manager to close a large position quickly and at low cost. Secondly, it is important to remember that we have data of future contracts and, as everybody knows, they have a finite life limited by their maturity. For our study, we have considered series considering the expiration day as the timing of rollover. We have calculated the rollover day continuous return as the logarithm of the quotient between the closing price of the first maturity and the previous price of such maturity. On the following day the return is obtained in a similar way but considering the closing prices of the new first maturity contract.

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[70] For further details, see http://www.eurexchange.com/trading/products_en.html.
[71] We have not considered in this study the price series of coal because this commodity is usually traded Over the Counter and it is not as accessible for investment purposes as the other two commodities considered.

We will perform the mean-variance analysis 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 the daily returns in a week.

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]

Energy variables present quite different means and standard deviation levels. While the Brent presents a positive mean and a standard deviation of 25.15%, the Natural Gas presents a very negative mean and a high standard deviation. Unsurprisingly, the fixed income assets are those with lower standard deviation and in this case they present negative returns. Note that, as expected, the bonds with nearer maturity have a smaller variance. The Euro Stoxx 50 presents higher levels of returns than the other variables considered and a standard deviation around 15%. In the next section, we study whether including the EUAs in six portfolios made up of different combinations of those assets increases the European investor efficient set.

4.4. IS IT WORTH INVESTING IN CO_2 AS A PORTFOLIO COMPONENT?

To analyse the impact of the EUAs on a diversified portfolio, we have considered that the investor has the possibility to invest in traditional investment assets (stocks and bonds), commodities (Brent and Natural Gas), and EUAs. As we have seen in the previous section, EUAs are considered in the literature as a commodity. However, Borak et al. (2006) conclude that there are substantial differences in the behaviour of

EUAs and other commodity prices. If those differences were not too important, we would expect that the contribution of the CO_2 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.

Additionally, by analysing the effects of introducing EUAs in different portfolios with and without energy commodities, we are taking into account two different types of investors that participate in the EU ETS. In the first group we find the investors that do not have carbon reduction obligations and thus we can consider that their diversified portfolio may or not include energy variables. In the second group of investors, we find the companies with carbon reduction targets that probably already have energy variables in their portfolios. Note that these latter types of investors are not only interested in diversifying their portfolios, but they may also hedge the risk of CO_2 price variation.

4.4.1. Correlation Analysis

As is well known, one of the main conditions of the asset that is going to be introduced in a portfolio with the objective of increasing the investor opportunity set, is that it has to present low or negative correlation with the assets already considered in the portfolio. In Table 3 we present the correlation analysis using weekly returns for the period from April 2005 to January 2008 between all assets taken into account in the study: Phase I CO_2, Phase II CO_2, Brent, Natural Gas, Euro Schatz Futures, Euro Bobl Futures, Euro Bund Futures, and the Euro Stoxx50.

[Please, insert Table 3].

Table 3 shows that the correlation between the Euro Stoxx 50 and the fixed income is negative and statistically significant. Additionally, the correlation with the other assets considered is also negative but not statistically significant. We also observed that the fixed income at short, middle or long term contracts are much correlated (correlations higher than 80%) and that Brent and Natural Gas series are not correlated. Another important aspect to comment on is that Phase I returns have positive statistically significant correlations with most of the assets in the portfolio. It is only not correlated with Euro Bolb Futures and Euro Bund Futures. The Phase II returns are only positively and statistically correlated with Brent returns. Finally, the correlation between the two EUA contracts is quite important during the period studied (35 %) but this is not especially relevant in our case because, as we will justify in section 4.2., we are going to study the impact on the portfolio standard deviation and return of each of the Phases considered separately.

Additionally, the correlation between two assets may differ under varying market conditions and consequently, it is important to determine how a candidate asset behaves during the extreme performance weeks. We would be interested in incorporating a new asset in a well diversified portfolio if it has a low or negative correlation with the other assets in the portfolio and, particularly, if this correlation occurs with negative external conditions. Following Karavas (2000), we have obtained the returns of CO_2 prices for both Phases of the EU ETS for the worst performance weeks of the energy series, the fixed income, and the Euro Stoxx 50. Specifically, we have obtained the mean of the returns that were higher than the percentile 99 (95) and the mean of the returns that were lower than the percentile 1 (5) for the energy variables, the fixed income, and the Euro Stoxx 50 and we have compared them with the mean of the CO_2 returns for both phases of the EU ETS for the same weeks. The results are presented in Table 4. In Panel A (B) we consider the 5% (1%) worst and best returns of energy variables, the fixed income, and Euro Stoxx 50.

[Please, insert Table 4].

During the worst energy week returns, the Phase I contract correlation with energy variables is positive. The EUAs Phase I returns behave in the same way as the energy variables and this is especially pronounced in the case of the 5% worst energy returns where the Phase I contract loses an average of 33% of its value. During the worst Euro Stoxx 50 performance weeks, the correlation with EUA Phase I returns is negative for both carbon contracts and thus this asset could increase the investors efficient set. The case of the Phase II returns correlation with energy variables is also positive but while the energy variables lose an average of 11% of their value, during those weeks the Phase II contract only loses 2% of its value. In the case of the 5% worst performance weeks of the fixed income, the CO_2 returns are always positive. These results indicate that the carbon contracts are probably not a good diversification asset in a portfolio with energy contracts but it could be a good diversification asset in a portfolio made up of traditional investments such as stocks and bonds. Those results are coherent with the high correlation of CO_2 Phase I and Phase II with the energy variables that we have seen in the previous section and the non statistical significant correlation of Phase II returns with the Euro Stoxx 50.

4.4.2. Diversified Portfolios Performance

Now we are going to consider several portfolios with different combinations of assets in order to analyse the performance of each one of them. Specifically, we have considered six different portfolios: Portfolio I is made up of stocks and bonds, Portfolio II is formed by stocks, bonds, and commodities, Portfolio III includes equities, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds, and Phase II EUAs, Portfolio V consists of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is comprised of stock, bonds, commodities, and Phase II EUAs. Note that when we consider the EUA as an investment asset in the portfolio, we never consider the possibility of investing together in Phase I and Phase II EUAs. The reason for such a choice is that, although it is no longer possible to invest in Phase I EUAs (remember that the trade of such asset finished in December 2007), it is interesting, on the one hand, to study what happened during the Phase I of the EU ETS, and on the other hand, to analyse the effects of investing in Phase II EUAs on their own. Specifically, following Karavas (2000), the composition of the portfolios and the weights we have considered are the following:

- Portfolio I: 50% stocks and 50% bonds,
- Portfolio II: 80% Portfolio I and 20% energy,
- Portfolio III: 80% Portfolio I and 20% CO_2 Phase I,
- Portfolio IV: 80% Portfolio I and 20% CO_2 Phase II,
- Portfolio V: 80% Portfolio I, 10% energy and 10% CO_2 Phase I,
- Portfolio VI: 80% Portfolio I, 10% energy and 10% CO_2 Phase II.

Using this approach, we are going to assume that short sales are not allowed and that 100% of the wealth is invested in the portfolio. In section 4.3, we will calculate the optimal portfolios weights allowing for short sales for all those portfolios, and we will show that we are able to obtain better returns for the same levels of standard deviation.

In Table 5 Panel A, the mean, the variance, the standard deviation, the minimum, the maximum, and the Sharpe Ratio of the six portfolios are presented.

[Please, insert Table 5].

If we focus on Panel A of Table 5, we observe that the Sharpe Ratios of all portfolios except for Portfolios I and IV (0.2608 and 0.1778 respectively) are negative. Despite this, as show in Table 1 and Table 2, except for the case of the Euro Stoxx 50, the Brent, and the CO_2 Phase II, the Sharpe Ratios obtained for the assets considered separately are also negative and most of the times smaller, in absolute terms, than those of the portfolios.[72]

Figure 4 shows the return-standard deviation trade-off of the assets considered individually and the return-standard deviation trade-off of the six portfolios presented before. In Figure 4-A the asset trade-off obtained is shown, in Figure 4-B there is a zoom of the assets up to a standard deviation of 60%.

[Please, insert Figure 4].

Additionally, Figure 4-C presents the return-standard deviation trade-off of the portfolios presented above. As we can appreciate, Portfolio I dominates all the other portfolios as it has the highest return for the lowest standard deviation. The worst portfolio is Portfolio III. It presents a low expected return (more specifically, a negative return) and a high standard deviation. Remember that Portfolio I is the one with traditional investment assets (50% stocks and 50% bonds) and Portfolio III is the one that includes 80% of traditional assets and 20% of CO_2 Phase I contract.

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 forecasts that do not accurately reflect the relative expected

[72] Note that during the sample period analysed most of the assets considered had lower average returns than the risk-free asset and obviously a higher standard deviation. This explains the negative Sharpe ratios.

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 continue to hold as long as the inputs have 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.

Following Karavas (2000) and with the purpose of contemplating this problem, we have identified portfolio allocations by obtaining the expected returns 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 (-0.0913) and we have obtained the expected returns for each asset imposing the fixed Sharpe Ratio for all assets.[73] 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.

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.

In Table 5, Panel B we present the mean and the Sharpe Ratio using the risk-adjusted returns approach. As we have seen, the other variables presented in Panel A of Table 5 do not change when considering risk-adjusted returns. As we can appreciate in Panel A,

[73] Note that this Sharpe ratio is coherent with the results obtained previously. As most of the assets considered had a negative Sharpe ratio during the sample period analysed, the historical relationship between returns and standard deviation in global terms is also negative.

the Sharpe Ratios all become negative (with the exception of Brent and Euro Stoxx 50). However, the Sharpe Ratios of the individual assets obtained with the risk-adjusted returns, are smaller in absolute terms than those of the portfolios (see last column of Table 1 and Table 2).

Additionally, Figure 5 presents the return-standard deviation trade-off of the assets and the portfolios considered in the study using risk-adjusted returns.

[Please, insert Figure 5]

The results are similar to those obtained using historical returns, and presented before. As we have seen, the standard deviation is the same independent of the methodology used. In both cases we again find some portfolios with high standard deviation and negative returns. Specifically, this is the case of the portfolios that introduce Phase I CO_2 allowances (Portfolio III and V).

The conclusion is that when using historical returns or risk-adjusted returns, we obtain portfolios with, in general, higher Sharpe Ratios in absolute terms, but still negative. Nevertheless, we have to take into account that when introducing EUAs in the portfolios III, IV, V, and VI, we have considered a positive investment of 20% of the total wealth invested in the portfolios III and IV, and a positive investment of 10% of the total wealth invested in the portfolios V and VI. Probably, these percentages of EUAs are too high. Consequently, the standard deviation of the portfolio increases more than the expected returns when introducing these new assets (that present a high individual standard deviation not compensated by their low expected returns). In section 4.3, we will obtain the optimal weights of the combination of assets for the six portfolios considered in the study.

4.4.3. Efficient Frontiers: Obtaining and Results

To obtain the efficient frontiers, we use the mean-variance methodology. We consider the six possibilities of asset combinations taken into account in the previous section and we compare them. Following the traditional methodology of the rule “expected returns – variance of returns” proposed by Markowitz (1952), the investors are faced with the trade-off between return and standard deviation; that is, they have to solve an optimisation problem which can be specified as follows:

$$\min_{\{w_j\,;\,j=1,\ldots N\}} \sigma_P^{\,2}$$
$$s.t.$$
$$\sum_{j=1}^{N} \omega_j E[R_j] = E[R_P]$$
$$\sum_{j=1}^{N} \omega_j = 1$$

ω_j is the weight in the portfolio of asset *j*, there are *N* assets, $\sigma_P^{\,2}$ is the portfolio variance, $E[R_j]$ is the expected return of asset *j*, and $E[R_P]$ is the expected return of the portfolio. Note that the restrictions of this problem allow for short selling, meaning that it is not necessary that $\omega_j > 0$. Therefore, the objective of the investors that face this optimisation problem is to minimize the standard deviation for an expected return. Note that by choosing different expected returns, we are able to generate the efficient frontier with all the efficient portfolios (those portfolios that provide the lowest standard deviation for a given expected return or equivalently, the greatest expected return for a given level of standard deviation).

We have compared the efficient frontiers by obtaining the solution to the minimization problem using the “solver” function of Excel. We have obtained the optimal weights for the combinations of assets of the six portfolios considered in the previous section. Additionally, as the method used to obtain the expected returns is determinant in the results of the minimization problem, we have considered the two possibilities for obtaining the expected returns: Historical Returns and Risk-Adjusted Returns, in line with the previous section.

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 in the portfolios are obtained using historical returns. As we can appreciate, in this case the combination of assets that allows for a better efficient frontier match with the composition of Portfolio V. That is, if we introduce energy assets and CO_2 Phase I to the traditional portfolio made up of stocks and bonds, the opportunities possibilities for the investors increase, allowing investment in portfolios with higher returns for the same levels of standard deviations.

The next best efficient frontier is the one that corresponds to Portfolio VI combination. This portfolio is made up of traditional investments, energy and CO_2 Phase II. However, this portfolio does not offer a big difference in efficiency terms neither from Portfolio II, which is made up of traditional investments and energy assets, nor from Portfolio III, which is made up of traditional investments and CO_2 Phase I. In the last positions we find the efficient frontier that corresponds to Portfolio IV, which is made up of traditional investments and CO_2 Phase II and that presents a slightly higher efficiency curve than Portfolio I which is exclusively made up of traditional investments (stock and bonds).

In Figure 6-B, the efficient frontiers for the same asset combination in the different portfolios are obtained using the risk-adjusted returns. The results are basically the same. The most interesting portfolio in terms of returns adjusted by risk to standard deviation is again Portfolio V (traditional investment, energy, and CO_2 Phase I). The difference from the previous results is that the portfolio made up of traditional investments and CO_2 Phase I (Portfolio III) is the next one that allows for a large efficient frontier. The order of the other portfolios is the same as presented above (Portfolio VI presents a higher efficient frontier than Portfolio II and Portfolio IV, and Portfolio I is the one that allows a smaller space of investment opportunities).

The main conclusions of this part of the section is that including CO_2 Phase I and Phase II can improve the investment opportunity set for an investor who initially invests in traditional investments (stocks and fixed income). However, the opportunities that the CO_2 Phase I investment presented in this sense, were much more important that those presented by the investment on CO_2 Phase II during the sample period. If we consider an investor that already had energy variables in his portfolio, only the investment in CO_2 Phase I could increase his investment opportunities. In contrast, independently of the method used to obtain the expected returns, we find that the portfolio that includes energy variables always allows for better combinations of returns and standard deviation than those that include CO_2 Phase II.

These results are coherent with the previous results presented throughout the article. The fact that CO_2 Phase I contracts presented very low returns with a very high standard deviation, jointly with the consideration of allowing short sales, causes the selling of CO_2 Phase I contract to increase substantially the investment opportunity set. On the other hand, the CO_2 Phase II contract also had a very high standard deviation compared to energy variables or to the traditional investment, but not such high (or low) returns as to convert it into an attractive investment to buy (or sell). Additionally, both CO_2 contracts have positive and statistically significant correlations with Brent. This could explain why introducing CO_2 contracts in a well diversified portfolio with equities and fixed incomes, which are correlated to none of the CO_2 contracts, increases the investment opportunity set, but this is not the case when the well diversified portfolio already has energy variables. As explained before, the case of CO_2 Phase I is a particular one due to its expected returns and standard deviation.

4.4.4. Optimal Weights of the Different Assets Considered in the Portfolio

Following this reasoning, 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. This is the reason why we are also interested in the weights of each sort of asset in each one of the optimal portfolios. For each of the six portfolios, we have considered three objective returns, and we have obtained the minimum variance combinations of assets in the portfolio that give us that return. Specifically we have considered a return of 3%, 5% and 10% as the objective return in order to obtain the optimal weights of assets. Figure 7 presents those results using the historical returns.

[Please, insert Figure 7].

As we can appreciate in Figure 7, the optimal portfolios have many large long and short positions. Specifically, in all of them there is a large short position of Euro Bolb Futures and a large long position in Euro Schatz Futures and in Euro Bund Futures. These results are not surprising since, 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.

When we consider historical returns, our particular results show that, in order to obtain a return up to 10%, the percentage of the wealth invested in CO_2 is relatively small in all cases, both if we take into account that there are energy contracts in the portfolio or not, and both if we consider Phase I or Phase II.

In the case, we suppose that there are no energy contracts in the portfolio and that we introduce CO_2 Phase I (Portfolio III), we find that the sign of the investment is negative (which means that we should sell that contract) and that it represents 3% of the total wealth. The sign obtained enforces the commentary done previously about the way of introducing this new asset in a traditional portfolio. Allowing for short selling is the only way of obtaining a participation of CO_2 in the portfolio. Additionally, the amount is comparatively small with other components of the portfolio. A possible explanation is that with the introduction of this asset in the portfolio, the trade-off between return and standard deviation is diminished due to the high standard deviation that the inclusion of CO_2 Phase I introduces into the portfolio.

If, instead of CO_2 Phase I, we introduce CO_2 Phase II in a portfolio without energy variables (Portfolio IV), the sign is positive (in this case we should buy that contract) and represents 5% of the total wealth in the portfolio. The explanation of a positive sign is that the expected return for CO_2 Phase II is positive. The low participation in the optimal portfolio of this asset is again its high historical standard deviation. Note that the weights obtained in Portfolio I, the one that takes into account only stock and fixed income, for each of its components does not change substantially with the introduction of CO_2 either Phase I or Phase II.

In the case where we consider that there are already energy contracts in the portfolio (Portfolio II, V, and VI), the results do not change substantially. The participation of the energy variables in the portfolio is also very small and the inclusion of CO_2 Phase I or CO_2 Phase II is similar to the case where we do not consider energy variables in the optimal portfolio. Those results are coherent with the fact that the mean-variance model tends to overweight (underweight) those securities that performed well (poorly) in the reference period of time.

Note that in this figure we can also appreciate which optimal portfolios offer the smallest standard deviation for the same return (3%, 5%, and 10%) and thus the position of the efficient frontiers in the return-standard deviation space.

These commentaries vary substantially when we consider the Risk-Adjusted returns. These results are shown in Figure 8.

[Please, insert Figure 8].

As has been said, in this case, the returns are adjusted to impose the same Sharpe Ratio to all assets (Sharpe Ratio equals to -0.0913). As shown in Table 1, 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 in the portfolio. As we can appreciate in Figure 8, 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. EUAs are introduced in all cases with selling positions and again, allowing for short sales is the only way of having CO_2 in the portfolio (both Phase I and Phase II).

4.5. SUMMARY AND CONCLUDING REMARKS

Since January 2005 two sorts of EUAs have been traded: EUA Phase I and EUA Phase II. However, since April 2008, as Phase I allowances have all been surrendered or cancelled, it has only been possible to trade EUA Phase II. Additionally, the trading volume on European carbon markets is increasing, and thus the interest in studying the implications of these new assets in portfolio management.

In this article we have analysed the characteristics of EUAs Phase I and Phase II as a sole investment. We have confirmed that both assets present low returns and high standard deviations and thus present a low Sharpe Ratio (especially the Phase I EUAs). Consequently those assets are not convenient as investing assets. However, if we consider the negative return of Phase I EUAs, we find an opportunity by selling this asset.

We have also studied the impact of including these assets in a diversified portfolio. We have taken into account six different portfolio compositions and we have obtained the efficient curves for each of these portfolios. We have performed this analysis using historical returns and risk-adjusted returns and we find quite similar results. We have discovered that including CO_2 Phase I and Phase II can improve the investment opportunity set for an investor that initially invests in traditional assets (stocks and fixed income). However, the opportunities presented by the CO_2 Phase I in this sense, were much more important than those presented by the investment on CO_2 Phase II during the sample period. If we consider an investor that already had energy variables in his portfolio, only the investment in CO_2 Phase I could increase his investment opportunities. In contrast, independently of the method used to obtain the expected returns we find that the portfolio that includes energy variables always allows for better combinations of returns and standard deviation than those that include CO_2 Phase II.

Finally, we have analysed how to incorporate EUAs into an optimal portfolio considering an objective return of 3%, 5%, or 10%. We find that the weights are not too important and that in most of the cases it is indispensable to allow for short sales in order to incorporate EUAs in an optimal and well diversified portfolio, especially in the case of Phase I EUAs, whose price was essentially zero during 2007.

Table 1: Descriptive Statistics of Assets Performance. May 2005 – January 2008.

This table presents the mean, the variance, the standard deviation, the minimum (Min), and the maximum (Max), and the Sharpe Ratio of both CO_2 contracts (CO_2 Phase I (II) representing Phase I (II) prices) using weekly historical returns. All results except the Sharpe Ratio are annualized and presented in percentage. The last column shows the Risk-Adjusted expected returns (with Sharpe Ratio = -0.0913).

	Mean	Variance	Standard Deviation	Min	Max	Sharpe Ratio	Risk-Adjusted Expected Return
CO_2 Phase I	-231.61	33815.71	183.89	-207.94	109.86	-1.2769	-27.66
CO_2 Phase II	7.09	3120.75	55.86	-50.01	20.73	0.0696	0.35

Table 2: Descriptive Statistics of Asset Performance. May 2005 – January 2008.

In this table, the mean, the variance, the standard deviation, the minimum (Min) and the maximum (Max), and the Sharpe Ratio of for the Brent, Natural Gas, the three fixed income contracts considered (Euro Schatz Futures, Euro Bobl Futures, and Euro Bund Futures), and the Dow Jones Euro Stoxx 50 using weekly historical returns are shown. All results except the Sharpe Ratio are annualized and presented in percentage. The last column shows the Risk-Adjusted expected returns (with Sharpe Ratio = -0.0913).

	Mean	Variance	Standard Deviation	Min	Max	Sharpe Ratio	Risk-Adjusted Expected Return
Brent	6.47	632.54	25.15	-8.31	8.73	0.1301	2.62
Natural Gas	-85.00	4931.73	70.23	-33.27	32.93	-1.2559	-1.30
Schatz	-0.50	1.10	1.05	-0.35	0.48	-3.5237	3.20
Bobl	-0.75	6.61	2.57	-0.77	1.08	-1.5344	3.19
Bund	-0.62	18.05	4.25	-1.38	1.57	-0.8980	3.18
Euro Stoxx 50	10.64	211.05	14.53	-6.06	5.30	0.5125	3.01

Table 3: Correlation Analysis among Assets.

Correlation of the weekly returns from April 2005 to January 2008 among all the assets considered in the study: Phase I CO_2, Phase II CO_2, Brent, Natural Gas, Euro Schatz Futures, Euro Bobl Futures, Euro Bund Futures, and the Euro Stoxx50. 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.

	Euro Stoxx 50	CO_2 Phase I	CO_2 Phase II	Brent	Natural Gas	Schatz	Bobl
CO_2 Phase I	-0.0973	1*					
CO_2Phase II	-0.0039	0.3768*	1*				
Brent	-0.0142	0.1960*	0.2111*	1*			
Natural Gas	-0.0656	0.1717*	0.0969	0.1312	1*		
Schatz	-0.1292	-0.1593	0.0003	0.0370	0.0275	1*	
Bobl	-0.3464*	0.2147*	0.1073	0.0339	0.0440	0.0679	1*
Bund	-0.3326*	0.1562	0.0921	-0.0249	0.0674	0.0439	0.9333*

Table 4: CO_2 Returns during the Worst and Best Energy, Fixed Income, and Euro Stoxx 50 Performance Periods.

This table presents the mean returns during the worst and best periods of the energy variables, the fixed income, and the Euro Stoxx 50. Panel A (B) takes into account the 5% (1%). In each Panel, column 2 (3) shows the returns during the worst (best) weeks for energy variables, column 4 (5) presents the returns during the worst (best) weeks for the fixed income variables, and column 6 (7) the returns during the worst (best) weeks for the Euro Stoxx 50. The data used are the weekly returns from April 2005 to January 2008.

Panel A: CO_2 Returns on the 5 % Worst Returns of Energy, Fixed Income, and Euro Stoxx 50.

	Energy Returns		Fixed Income Returns		Euro Stoxx 50 Returns	
	Worst	Best	Worst	Best	Worst	Best
CO_2 Phase I Returns	-33	2	1	9	8	-9
CO_2 Phase II Returns	-2	1	3	3	4	0
Energy Returns	-11	12				
Fixed Income Returns			-1	1		
Euro Stoxx 50 Returns					-5	4

Panel B: CO_2 Returns on the 1 % Worst Returns of Energy, Fixed Income, and Euro Stoxx 50.

	Energy Returns		Fixed Income Returns		Euro Stoxx 50 Returns	
	Worst	Best	Worst	Best	Worst	Best
CO_2 Phase I Returns	-3	11	-5	0	0	8
CO_2 Phase II Returns	1	3	3	4	5	-1
Energy Returns	-14	19				
Fixed Income Returns			-1	1		
Euro Stoxx 50 Returns					-6	5

Table 5: Descriptive Statistics of Portfolio Performance Expressed in Percentage.

In Panel A of this table, the mean, the variance, the standard deviation, the minimum (Min.), the maximum (Max), and the Sharpe Ratio of the six portfolios are presented using weekly historical returns for the period from April 2005 to January 2008. In Panel B we present the mean and the Sharpe Ratio using the risk-adjusted returns approach using the same sample period. The portfolios are weighted as follows: Portfolio I is made up of stocks and bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs.

Panel A: Descriptive Statistics of Portfolio Performance May 2005- January 2008 in percentage. Historical returns.

	Mean	Variance	Standard Deviation	Min	Max	Sharpe Ratio
PORTFOLIO I	5.01	48.33	6.95	-3.03	2.47	0.2608
PORTFOLIO II	-3.84	86.23	9.29	-2.80	3.94	-0.7584
PORTFOLIO III	-42.31	1353.22	36.79	-40.69	22.29	-1.2372
PORTFOLIO IV	5.43	156.96	12.53	-10.54	3.16	0.1778
PORTFOLIO V	-23.08	397.74	19.94	-20.79	11.56	-1.3176
PORTFOLIO VI	0.79	82.08	9.06	-5.91	2.33	-0.2657

Panel B: Descriptive Statistics of Portfolio Performance May 2005- January 2008 in percentage. Risk-Adjusted returns approach.

	Mean	Sharpe Ratio
PORTFOLIO I	3.09	-0.0019
PORTFOLIO II	2.61	-0.0088
PORTFOLIO III	-3.05	-0.0235
PORTFOLIO IV	2.55	-0.0072
PORTFOLIO V	-0.22	-0.0238
PORTFOLIO VI	2.57	-0.0095

Where for both Panels:

	EU Equity	EU Bonds	Energy	CO_2 Phase I	CO_2 Phase II
PORTFOLIO I	50%	50%			
PORTFOLIO II	40%	40%	20%		
PORTFOLIO III	40%	40%		20%	
PORTFOLIO IV	40%	40%			20%
PORTFOLIO V	40%	40%	10%	10%	
PORTFOLIO VI	40%	40%	10%		10%

Figure 1: CO_2 Phase I and CO_2 Phase II Price and Volume Evolution.

This figure shows the evolution of ECX CO_2 futures prices and volumes for Phase I and Phase II of the EU ETS from 22nd April 2005 to 31st January 2008. The prices are expressed in euros and the volume in number of contracts (each contract allows for the emission of 1000 tonnes of CO_2 equivalent).

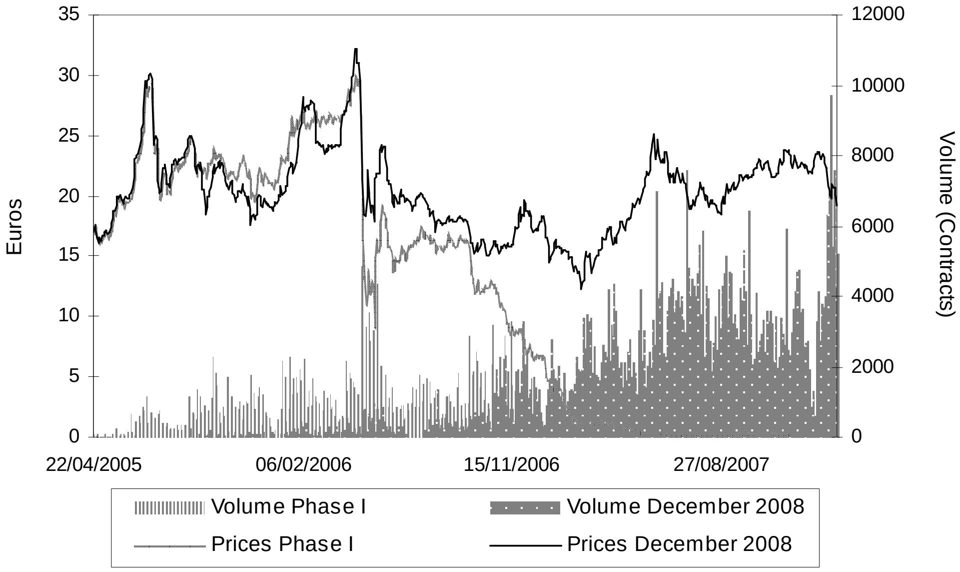


Figure 2: Volatility Evolution.

This figure shows the evolution of Phase I and Phase II CO_2 returns volatility. A moving standard deviation of 20 day sample is presented for the period from April 2005 to January 2008. The results are very similar if we consider sample periods of 10 and 5 weeks.

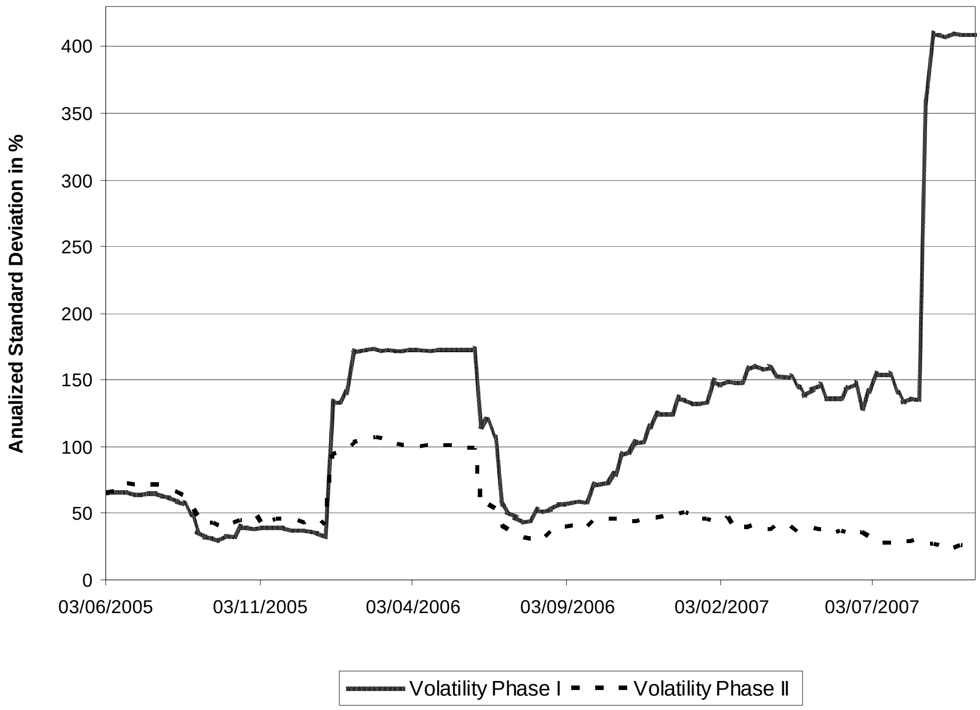


Figure 3: EUA Volumes in Carbon European Markets.

Cumulative volumes traded in the different European Carbon markets since the start of the trade in each market to January 2008. Spot (futures) refers to the volume traded through spot (futures) contracts, and OTC refers to the volume traded through the LEBA members. Phase I (Phase II) refers to the EUAs concerning the Phase I (Phase II) of the EU ETS. BlueNext, EEX, and Nord Pool in the Spot by Markets figure correspond to the volume traded in those markets through spot contracts. EEX, Nord Pool, and ECX in the Futures by Markets figure correspond to the volume traded in those markets through futures contracts mixing up Phase I and Phase II contracts. The volumes are expressed in tonnes of CO_2-equivalent.

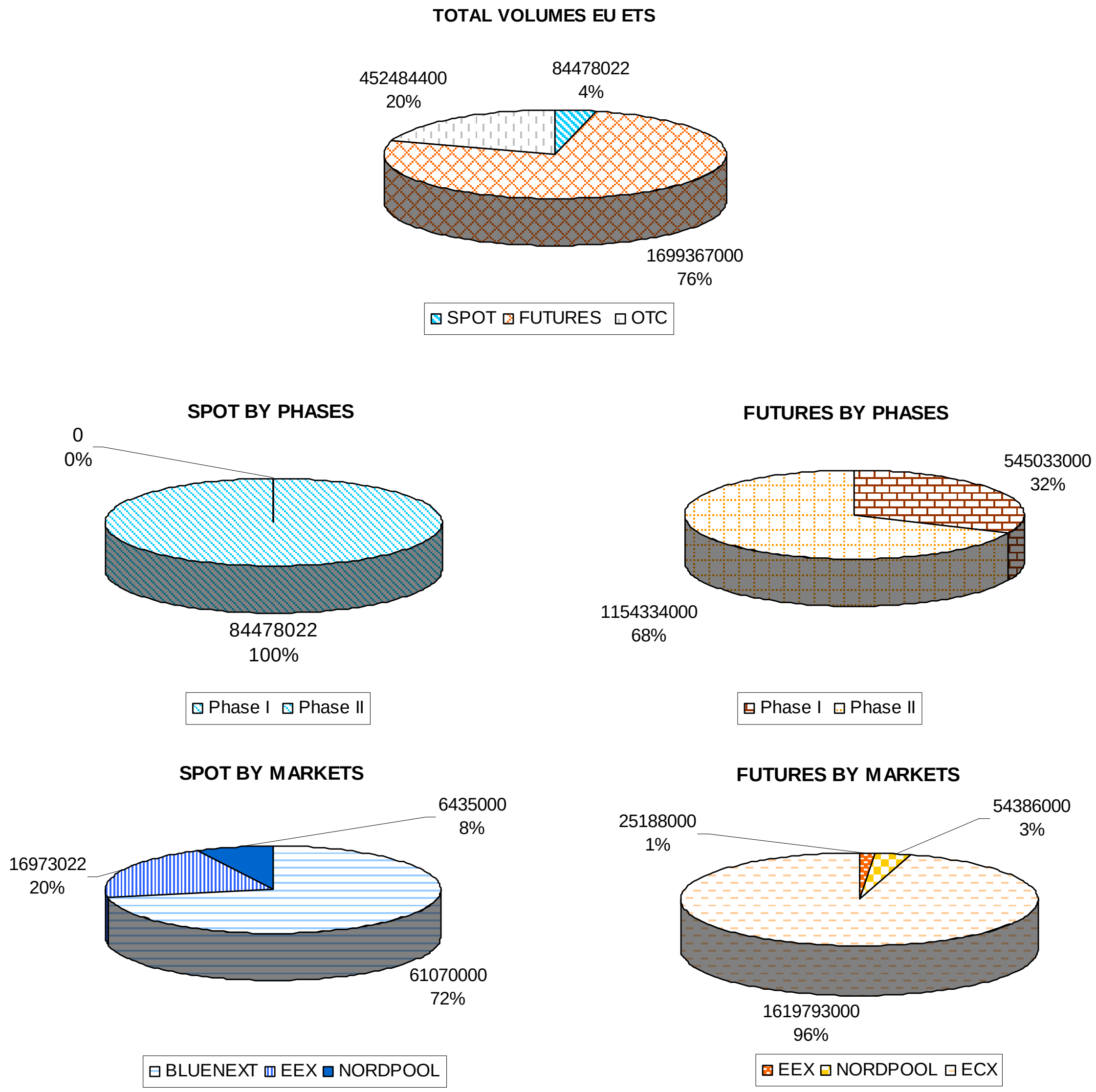


Figure 4: Mean-Standard Deviation Trade-Off with Historical Returns.

Figure 4-A and Figure 4-B show the Return and Standard Deviation Trade-off of the assets considered in this study. Figure 4-C shows the same information for the six portfolios considered in the study: Portfolio I is made up of stocks and bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs. All the figures show the results using Historical Returns.

Figure 4-A: Assets Return and Standard Deviation Trade-off.

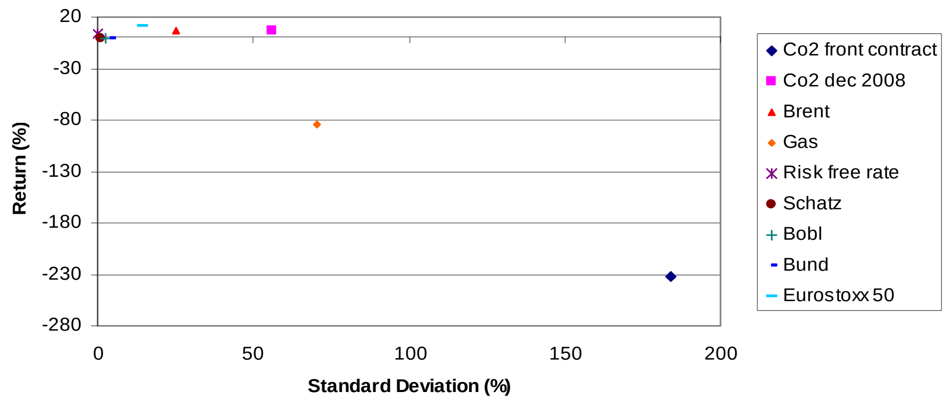


Figure 4-B: Detail Return and Standard Deviation Trade-off.

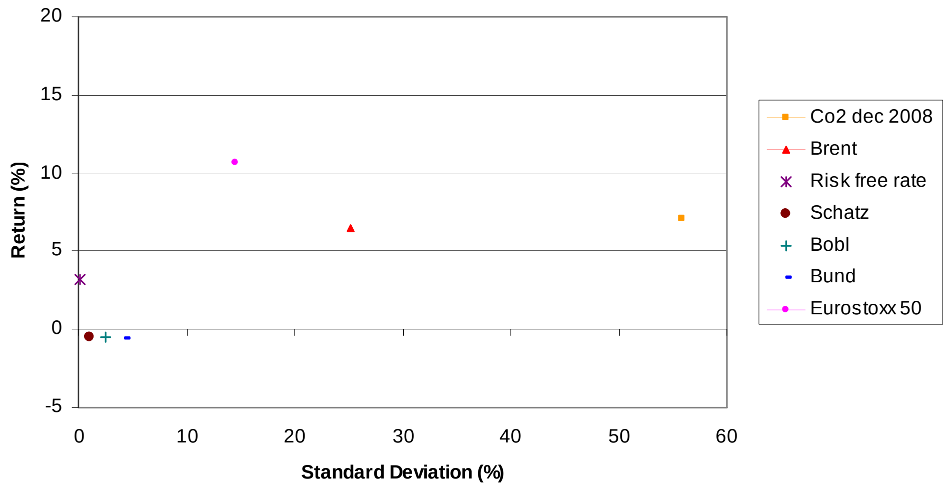


Figure 4-C: Portfolio Return and Standard Deviation Trade-off.

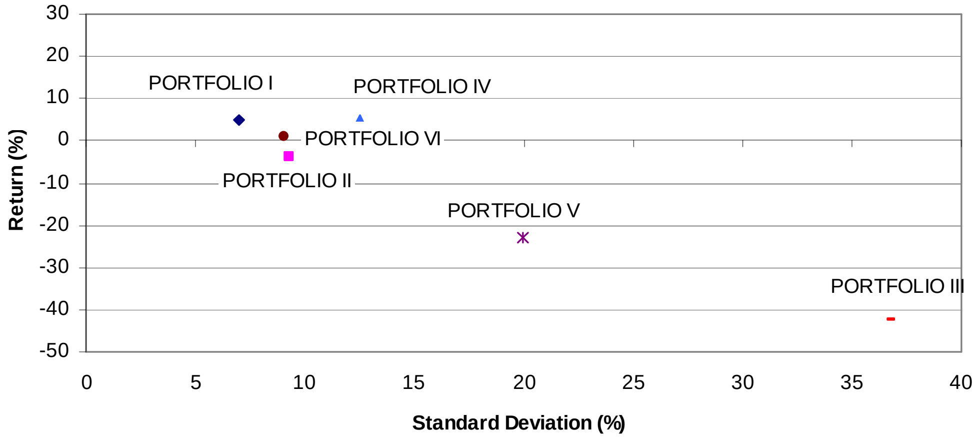


Figure 5: Mean- Standard Deviation Trade-Off. Risk-Adjusted Returns Approach.

Figure 5-A shows the Return and Standard Deviation Trade-Off of the assets considered in this study. Figure 5-B shows the same information for the six portfolios considered in the study: Portfolio I is made up of stocks and bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs. All the figures show the results using Risk-Adjusted Returns.

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

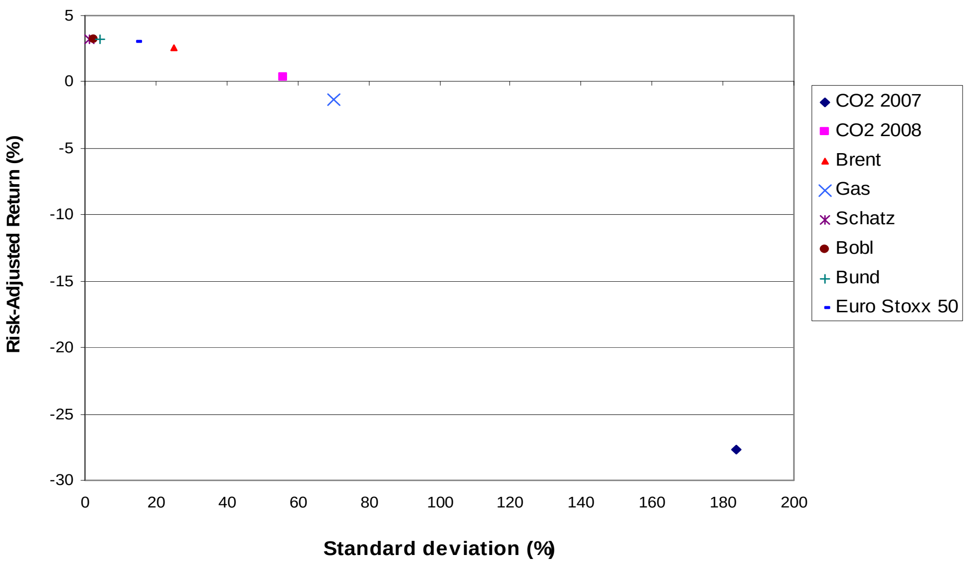


Figure 5-B: Portfolio Return and Standard Deviation Trade-off.

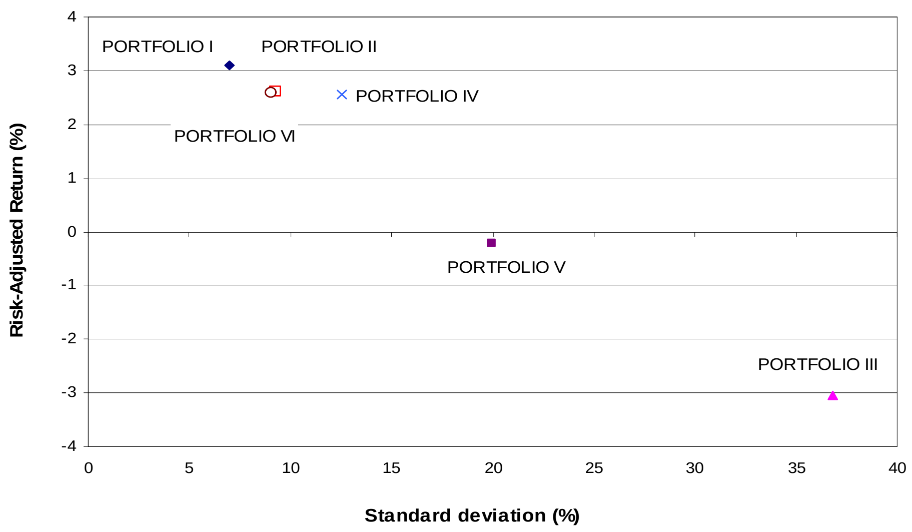


Figure 6: Efficient Frontier for the Different Portfolios Considered.

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 bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs.

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

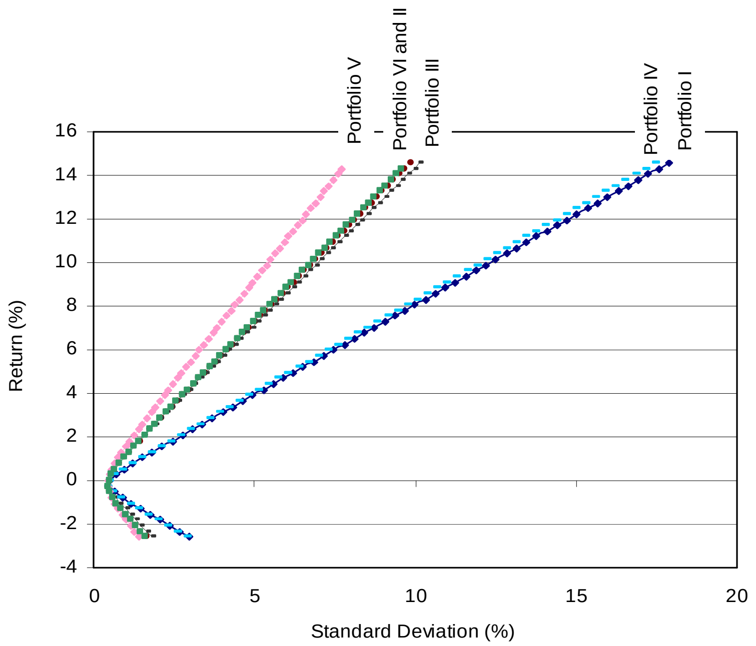


Figure 6-B: Efficient Frontier for the Portfolios Considered. Risk-Adjusted Returns.

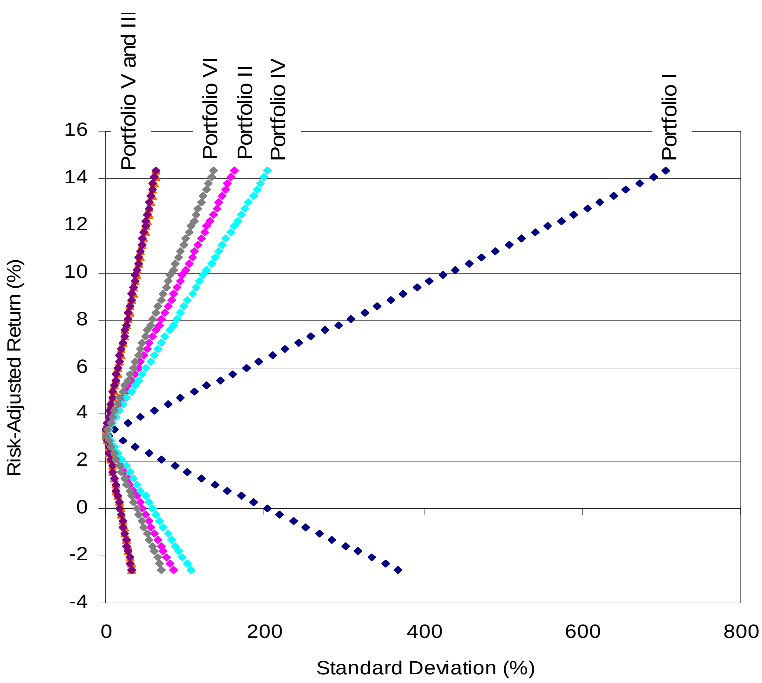


Figure 7: Assets Weights in the Efficient Frontier Portfolios. Historical Returns.

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 bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs. All the Panels show the results using Historical Returns.

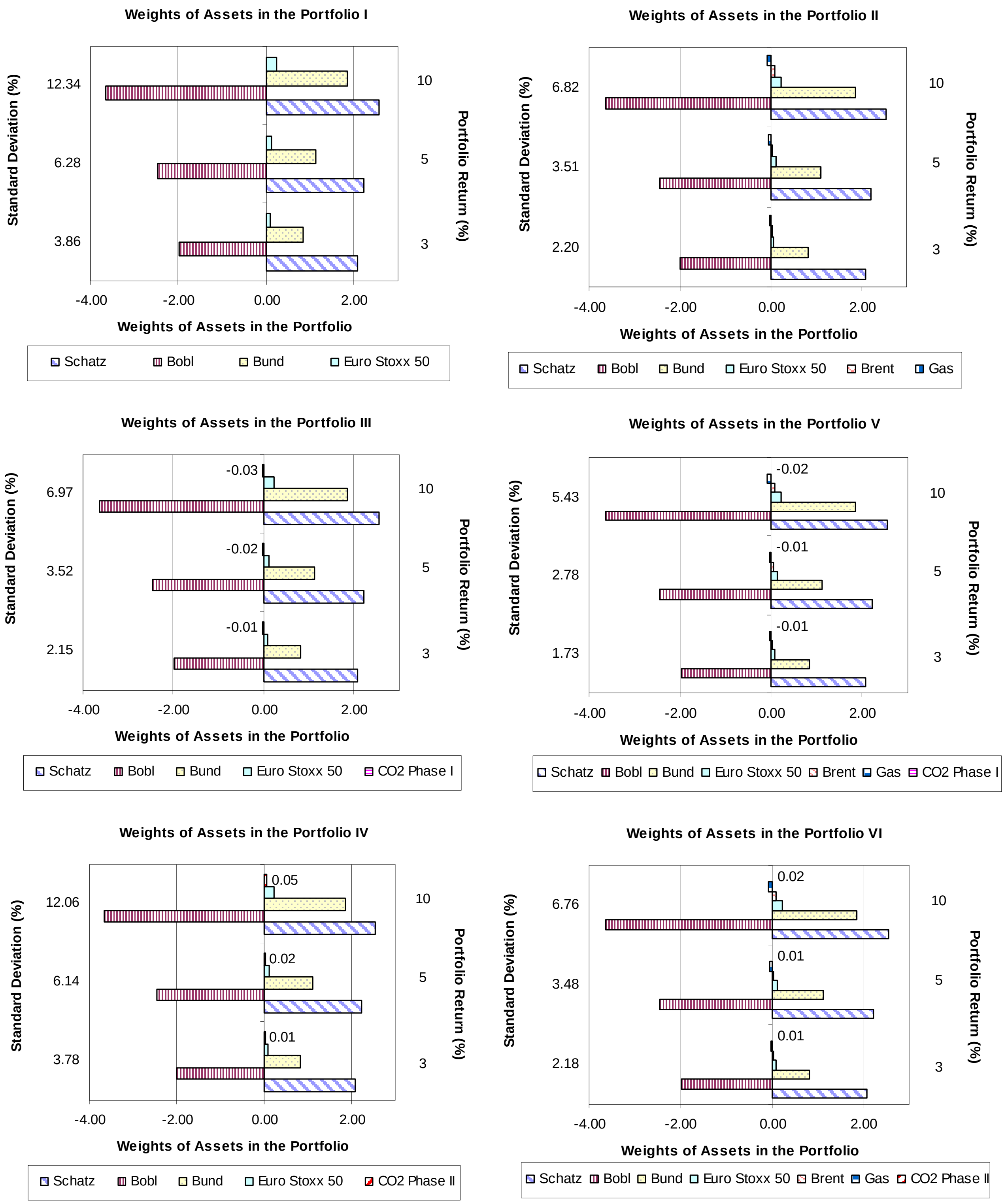
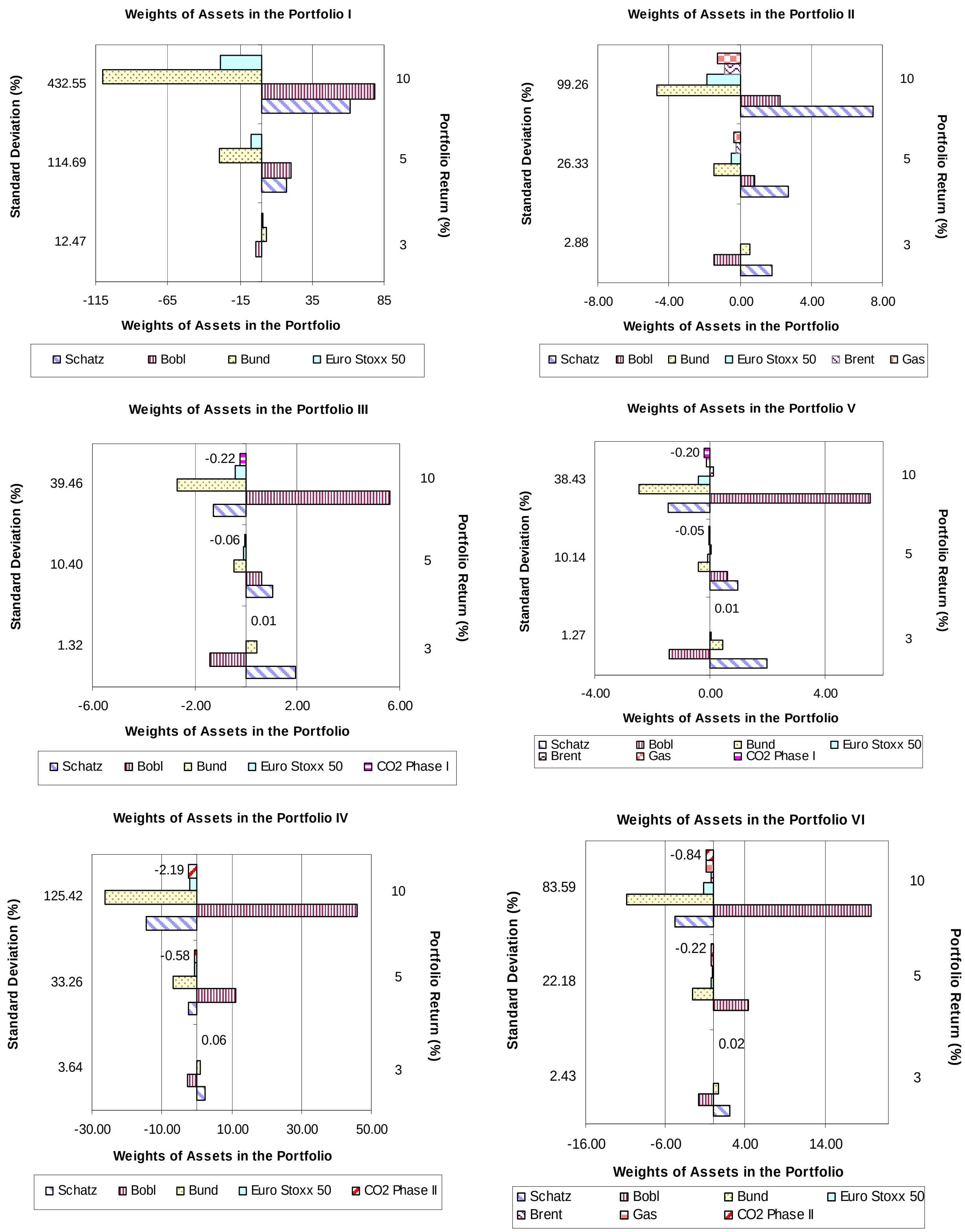


Figure 8: Asset Weights in the Efficient Frontier Portfolios. Risk-Adjusted Returns.

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 bonds, Portfolio II is made up of stocks, bonds, and commodities, Portfolio III is made up of stock, bonds, and Phase I EUAs, Portfolio IV is made up of stock, bonds and Phase II EUAs, Portfolio V is made up of stock, bonds, commodities, and Phase I EUAs, and finally, Portfolio VI is made up of stock, bonds, commodities, and Phase II EUAs. All the Panels show the results using Historical Returns.



CONCLUSIONS

Since February 2005 it has been possible to trade European Union Allowances for Phase I and Phase II of the European Union Emission Trading Scheme in organized markets. These new assets allow for the emission of one CO_2-equivalent tonne in Europe. Spot, Futures, and Options contracts have been traded since then with an exponentially increasing degree in different market places all around Europe. Additionally, other emission reduction permits are also traded in Europe and around the word, and thus the interest in studying from a financial point of view some of the most important questions about the behaviour and the features of this new market.

In this dissertation, we have answered some questions concerning the main characteristics of carbon markets, the determinants of prices, the efficiency of the CO_2 market, and portfolio management, among others. These questions are interesting not only to academics but also to market participants and regulators.

The dissertation is organized into four differentiated chapters that look at emissions trading from different perspectives. Chapter 1 is entitled *"CO_2 Trading"*. With the objective to make it easier to understand the other three parts, the aim of this chapter is to establish the context of carbon trading. In this chapter, we present the Kyoto Protocol and the three flexibility mechanisms, among which we find emissions trading. We have seen that there were many experiences previous to the European Union Emission Trading Scheme that concerned many types of allowances (SO_2, packaging recoveries notes or quotas in fisheries, for example) and that some countries had already traded with permits in order to face climate change (Denmark and UK, among others). Next we have focused on the functioning of the European Union Emission Trading Scheme and the market places in Europe where it is possible to trade European Union Allowances. We have illustrated that the most important spot (futures) market in terms of volume is BlueNext (European Climate Exchange (ECX)), and for the moment, only ECX allows for option trading on futures contracts of European Union Allowances. In terms of price behaviour we have shown that Phase I prices, independently of the market where they are negotiated, follow the same evolution and are on the same levels. This is also the case for Phase II prices.

Additionally, the linking possibilities of the European Union Emission Trading Scheme with the United Nation carbon markets are also analysed in this chapter. We emphasize the importance of the International Transaction Log and the role of both the developing and the economies-in-transition countries in mitigating the impact of climate change through the elaboration of reduction emissions projects that lead to Certificates of Emissions Reductions and Emission Reduction Units, respectively.

Chapter 2 is entitled *"CO_2 Prices, Energy and Weather"*. The aim of this chapter is to study what the factors are that determine short term CO_2 prices and to give some evidence of the rationality of this new market in its first year of functioning. Most of the theoretical models dealing with this question suggest that energy prices and weather factors could influence allowance prices. These factors are, in general, consistent with market agents' perceptions. In this paper we focus on the daily CO_2 returns during 2005 in an attempt to examine the underlying rationality of pricing behaviour during the first year of the European Union Emission Trading Scheme. In particular, in this study we analyse several models to corroborate the influence of energy and weather variables on CO_2 returns.

The results show that the most important variables in the determination of CO_2 returns were the Brent and natural gas returns. We also find evidence that extremely hot and cold days in Germany had a positive influence on daily CO_2 prices during the first year of compliance. In contrast, we also afford some surprising results such as the fact that neither the price of the most intensive emission source (coal) nor the switching effect between gas and coal returns, affect CO_2 returns. Nevertheless, all the variables that are statistically significant in our study, influence the carbon returns in the sense we would expect and therefore, we find some evidence of rationality in this market, meaning the daily forward prices do reflect underlying conditions at the micro-level and, therefore, carbon markets during 2005 were not as irrational as some participants and observers have suggested.

Chapter 3 is entitled *"The Impact of National Allocation Plans on CO_2 Prices"*. In this article we analyze CO_2 market efficiency. Specifically we study the effects of official information, coming from the European Commission, on the allowance returns and volatility. The European Commission announcements are numerous and sporadic and affect a sole price series. These are the reasons why we have adapted the Event Study methodology to our particular case and we have proposed a redefinition of the Mean Return Model methodology that we have named the Truncated Mean model.

Related to the effects of National Allocation Plans announcements on carbon returns, we find that both Phase I and Phase II announcements have an influence on carbon returns on the day of the announcement and in a few cases on the following days. Surprisingly, we have also detected significant returns on days previous to the official announcement. Related to the variations in the volatility of carbon returns, we have not observed differences before and after the announcement. Both the presence of significant abnormal returns up to three days prior to a National Allocation Plan related event and the absence of volatility effects when the official information is revealed, suggest that there has been a leakage of information before the announcement.

These findings support the request made by the European Federation of Energy Traders (EFET, 2006) to the European Commission as a consequence of the release of real emissions data for 2005. Specifically the European Federation of Energy Traders asked for carbon price sensitive information that was *accurate, final and published in such a way as to be available to all market participants at the same time*

Chapter 4 is entitled *"CO_2 Prices and Portfolio Management"*. The topic that is analysed in this final chapter is the introduction of the two new sorts of assets (European Union Allowances for both Phase I and Phase II of the European Union Emission Trading Scheme) in a well diversified portfolio. In this last part of the dissertation we start by analysing the characteristics of the European Union Allowances for Phase I and Phase II as a sole investment. We have found that both assets present low returns and high standard deviations and thus present a low Sharpe Ratio (especially the Phase I European Union Allowances). Consequently those assets are not convenient as investing assets. However, if we consider the very low return of Phase I European Union Allowances, we would find an opportunity in selling this asset.

In order to analyse the impact of including these assets in a diversified portfolio, we have taken into account six different portfolio compositions and we have obtained the efficient curves for each of those portfolios. We have performed this analysis using historical returns and risk-adjusted returns and we find quite similar results. We have found that including CO_2 Phase I and Phase II can improve the opportunity set of investment for an investor that initially invested in traditional assets (stocks and fixed income). However, the opportunities that the CO_2 Phase I provided in this sense, were much more important than those that an investment in CO_2 Phase II offered during the sample period. If we consider an investor that already had energy variables in his portfolio, only the investment in CO_2 Phase I could increase the investor opportunity set. In contrast, independently of the method used to obtain the expected returns, we find that a portfolio that includes energy variables always allows for better combinations of returns and standard deviation than those that include CO_2 Phase II.

Finally, we have analysed how to incorporate the European Union Allowances in an optimal portfolio considering an objective return of 3%, 5%, or 10%. We find that the weights are not too important and that in most of the cases it is indispensable to allow for short sales in order to incorporate the European Union Allowances in an optimal and well diversified portfolio, especially in the case of Phase I European Union Allowances whose price was essentially zero during 2007.

As a global conclusion of this dissertation, we would like to underline that the European Union Emission Trading Scheme has succeeded in imposing a price on carbon emissions which was, following Lowrey (2006), perhaps one of its most important objectives. Additionally, following Stern (2006), one of the principal elements in efficiently facing climate change is the existence of a price for greenhouse gas emissions, and thus the importance of the European Union Emission Trading Scheme in establishing such a price. It is true that the price for Phase I of the European Union Emission Trading Scheme was so low that it did not encourage real emissions reductions but, as the European Commission pointed out, Phase I served to create the necessary experience for all market participants to succeed better in the next phase, and thus Phase I should be considered as a training phase.

Note that in this dissertation we have analysed the determinants of prices from the demand point of view. The reason for such a choice is that the offer of allowances is established politically. This leads to the increasing importance of public policies concerning climate change that become principal drivers of carbon prices.

Due to the small availability of data when we started with this dissertation (one year of data for the second chapter, two years of data for the third chapter, and three years of data for the last chapter) we have used throughout the dissertation non-parametric techniques in order to avoid suppositions on the statistical distribution of the returns. We also had to adapt, as in chapter 3, the methodology to our particular case, and in chapter 4 we were obliged to analyse the issue of portfolio management including European Union Allowances with a short term investment horizon. The natural expansion of this dissertation would be to consider longer sample periods and enlarge the amount of historical data. This will only be possible by waiting for the development of the European Union Emission Trading Scheme and the CO_2 markets. It will be necessary to constantly update chapter 1 and especially to follow the preparation of Phase III of the European Union Emission Trading Scheme and the post-Kyoto international agreement.

With regard to chapter 2, by considering longer price series we would be able to introduce other variables as determinants of CO_2 prices, both related to the economy and the weather. In the first case, we may think to introduce variables such as the evolution of the Gross Domestic Product (an increase in production should provoke an increase in the demand of energy and thus an increase in CO_2 prices). We could also think of taking into account the abatement activity which will be determinant for the equilibrium prices in the Phase II of the European Union Emission Trading Scheme. In the group of new weather variables, we might think about elements such as the amount of water in the reservoirs (a significant reduction in the level in reservoirs may provoke a reduction in hydroelectric production and could be relevant in determining CO_2 prices in the long run). Note that in both cases we are talking about variables that change over long periods of time and thus can not be used to analyse the CO_2 prices in the short run, but are perfectly justified in an analysis of CO_2 prices over the long term.

Concerning chapter 3, it would be interesting to consider if the existence of non-official announcements such as those published by Point Carbon has an impact on CO_2 prices. We have not considered these types of announcements for one main reason: the objective of the chapter was the analysis of the impact of *official* information on CO_2 prices.

Finally, regarding chapter 4, with longer price series we would be able to change the investor horizon and consider long run investors' interests. Questions such as if it would be financially interesting for a long run investor to invest in such volatile assets could be analysed, and we could determine the impact of changing the time horizon in portfolio management. Additionally, it would also be possible to analyse the hedging properties of these new assets against inflation or other macroeconomic variables that vary over longer periods of time. Finally, we could introduce CO_2 returns as an explicative factor in valuation models for companies that have legally binding reduction targets.

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