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Research Article

The price impacts of linking the European Union Emissions Trading Scheme to the Clean Development Mechanism

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Abstract Many countries have begun to look increasingly toward the Clean Development Mechanism (CDM) as one of the key tools to increase the cost effectiveness of fulfilling their compliance requirements with the Kyoto Protocol. It is believed, from a theoretical point of view, that linking emissions trading schemes to the Kyoto Protocol's flexible mechanisms can lead to a decrease in carbon prices and so a reduction of the overall compliance costs. This study provides an analysis of the relationship between the European Union Emissions Trading Scheme (EU ETS) and the CDM. The study considers the dynamic interactions between European allowance (EUA) prices and certified emission reduction (CER) prices, and uses time-series econometric techniques to test for the existence of long-term links and causal relations between the prices. Furthermore, the generalized impulse response analysis has been used to investigate temporal interactions among the variables. The results show that CER prices do not have a statistically significant effect on EUA prices; rather, it is the EUA prices that have driven CER prices during the period investigated. The constraint on the availability of CERs emanating from supplementarity and additionality criteria, as stipulated by the Kyoto Protocol, is one of the major factors that can be hypothesized to account for this finding.

Key words Carbon emissions trading scheme · Clean Development Mechanism · Certified emission reduction · Granger causality tests · Generalized impulse response function

1 Introduction

Most countries have ratified the Kyoto Protocol in an attempt to slow down and stabilize the pace of climate change. Under the Kyoto Protocol, the Annex B countries, industrialized countries, commit to reduce their emissions by an average of 5.2% below their 1990 levels over the commitment period 2008–2012. However, for mandated economies to meet their compliance requirements at the lowest possible cost, participants are also allowed to meet their reduction targets by purchasing emissions allowances or credits created through three flexible mechanisms: the emission trading scheme (ETS) by purchasing emissions permits in financial exchanges; the Clean Development Mechanism (CDM) by purchasing certified emission reductions (CERs) from projects in developing countries (non-Annex I countries); and joint implementation (JI) by purchasing emission reduction units (ERUs) from projects in other Annex B countries.

The CDM is considered by many industrialized countries as a more cost-effective way to respond to climate change. However, in order to ensure that the certified project activity reduces emissions more than would have otherwise occurred and to prevent industrialized countries from overusing project-based credits, the criteria of additionality and supplementarity have been stipulated by the Kyoto Protocol (UNFCCC 2002). These criteria impose some access restrictions on credits and make their use more sophisticated and reduce the attraction of cheap project-based credits for Annex B parties, thereby influencing their flexibility and cost effectiveness in efforts to reduce emissions.

The European Union (EU), under the Kyoto Protocol, is required to reduce its greenhouse gas emissions by an average of 8% below 1990 levels over the 2008–2012 period. The EU may do so through three main policies: domestic reductions through the European Union Emissions Trading Scheme (EU ETS) for energy-intensive sectors (EU 2003), domestic reductions outside the Emissions Trading Scheme for non-energy-intensive sectors, and emissions reductions abroad (European Commission 2003). To implement the latter, in 2003, the 15 EU member states planned to fill part of their Kyoto gap with 540 $MtCO_2e$ (megaton CO_2 equivalents) through the flexible Kyoto Mechanisms of CDM and JI (World Bank 2008). As a result, the European Commission decided to establish a link between the CDM and the EU ETS to increase the cost effectiveness of fulfilling obligations and to meet its target at minimal cost (EU 2004). This article sheds light on the price impacts of this link by considering the dynamic interaction between the price of European allowances and CERs under the current EU ETS regulations. In other words, with respect to EU compliance to Kyoto reduction commitments, the purpose of this article is to investigate whether linking the EU ETS to the CDM can lead to any significant cost saving by driving down the European allowance (EUA) prices.

From a theoretical point of view, because the marginal cost of abatement in developing countries is lower than in Annex B countries, the price of credits generated under the CDM should be lower than the EUA prices, although being equal value in terms of carbon emissions. This means that linking the EU ETS to the CDM indicates recognition of CERs as equivalent to EU allowances (that CERs can serve as important substitutes for high-priced EU ETS allowances) and will drive down EUA prices. This, in turn, leads to a reduction of the overall EU compliance costs with the Kyoto Protocol. In other words, by supplying excess credits, the demand for European allowances will be decreased, which, in turn, will lead to a decrease in EUA prices. Therefore, it is believed that linkage of the EU ETS to the Kyoto Protocol's mechanisms can increase the number of low-cost compliance options within the community scheme and it can lead to a reduction of the overall cost of compliance with the Kyoto Protocol (EU 2004). Such a step may also improve the liquidity of the EU ETS. However, the EU has imposed some restrictions on the availability of CERs for its member states and their operators owing to the supplementarity and the additionality criteria that can significantly influence the expected effects and, more specifically, the extent of the decline in EUA prices.

There are many studies dealing with carbon markets, and more specifically with the EU ETS, that provide comprehensive overviews on issues such as: context and history, allocation, competitiveness, distributional effects, market, finance, and trading (Betz et al. 2006; Christiansen and Wettestad 2003; Benz and Trück 2009; Böhringer et al. 2006; Ahman et al. 2007; Alberola et al. 2008; Weyant and Hill 1999; Weitzman 1974; Convery 2009). However, few studies have investigated the economic effects of linking the EU ETS to the CDM. These studies have mainly been carried out over the past several years and they have arrived at different results based on different assumptions about the supplementarity and additionality criteria and different approaches to modeling the issues (Anger et al. 2007; Criqui and Kitous 2003; Jotzo and Michaelowa 2002; Michaelowa et al. 2003; Anger 2008; Klepper and Peterson 2006; Langrock and Sterk 2004). For example, Criqui and Kitous (2003) showed that by linking the EU ETS to the CDM, the compliance costs of ETS sectors would reduce by about 60%. According to Klepper and Peterson (2006), in the case of the availability of hot air,[1] the price of carbon will drop to zero. Furthermore, Anger et al. (2007) showed that by linking the EU ETS to the CDM, the price of allowances would reduce to less than US $2.5 in a scenario in which the additionality issue is considered and the use of hot air is not allowed.

The present study is one of the first studies to analyze the economic effects of linking the EU ETS to the project-based Kyoto mechanism (CDM) through quantifying the price impacts of this link by using econometric evidence from the EU ETS and the CDM. Because the earlier studies were primarily theoretical in nature and they were based on numerical simulations, the analysis undertaken in this article is rather different.

To answer the question of whether the economy access to project-based abatement options in developing countries within linked EU ETS can induce large additional cost savings (through driving down EUA prices), this study uses time-series econometric techniques to test for existence of causal relation and long-run links between CER and EUA prices. The study used data on EUA prices (future contracts with expiry in December 2008) and secondary market CER (where guaranteed CERs are traded) 2008 and 2008–2012 prices from Point Carbon website. The models are estimated on a daily data sample from the 25 May 2007 to the 1 September 2008.

The findings should be helpful for countries that are considering whether and how to link up with the Kyoto Protocol flexible mechanisms in order to meet their targets at the lowest possible cost. By understanding how this link may or may not affect an emissions trading scheme and the extent to which CERs may

[1] The excess emission rights of transition economies with targets that are below their business-as-usual (BAU) levels resulting from the economic breakdown of their economies are called "hot air."

affect the permit prices, policymakers will be able to make better decisions to tackle climate change in the most cost-effective way by taking into account this link when designing an appropriate emission trading scheme.

The remainder of this article is structured as follows: Sect. 2 provides an overview over the CDM under the Kyoto Protocol, how it works, and the current situation of the CDM markets. Section 3 presents the models to investigate the interaction between CER and EU allowance prices and reports the empirical findings based on the estimated models. Section 4 summarizes the results and draws some conclusions.

2 Background on the Clean Development Mechanism

The Clean Development Mechanism was defined under Article 12 of the Kyoto Protocol in 1997 [United Nations Framework Convention on Climate Change (UNFCCC) 1997]. It was the first Kyoto mechanism that came into effect and the only method in which developing countries are involved to curb their greenhouse gas (GHG) emissions.

Developing countries can deliver large volumes of cost-effective emission abatements to meet the science-based emission reduction target. Therefore, the CDM was designed to make Annex B parties eligible to purchase CER credits, which are generated from investment in emission reduction projects in developing countries, in order to fulfill their compliance requirements in an economically efficient way.

The CDM Executive Board (EB), which operates under the authority of the Conference of the Parties (COP/MOP) of the United Nations Framework Convention on Climate Change (UNFCCC), supervises the CDM project activities. Seven steps should be taken so that CERs can be issued: (1) project design and formulation, (2) national approval, (3) validation and registration, (4) project financing, (5) monitoring, (6) verification and certification, and (7) issuance of CERs (UNEP 2004). The CERs can be issued by the EB once the CDM projects complete the registration process and the project can generate the credits from the starting date of the project activity. At the end of March 2008, about 30% of CDM projects, 978 out of 3188 CDM projects, were registered, and 2022 projects, or approximately two thirds of the projects, were at the validation stage (World Bank 2008). The CDM pipeline now consists of over 4500 projects and only one third of the projects have been registered (World Bank 2009).

Currently, three main types of CERs exist in the market: issued CERs, forward streams of CERs, and secondary market CERs[2]. Issued CERs refers to CERs that have been generated and issued by projects already undertaken. Forward streams of CERs are credits that are supposed to be generated by projects that are under construction and expected to commence between 2008 and 2012 (the first phase of the Kyoto Protocol). Carbon credits presented with a guarantee of delivery by some financial institution or a rated entity, such as a bank or fund,

[2] A market for options on CERs started to emerge in the second half of 2008 (World Bank 2009).

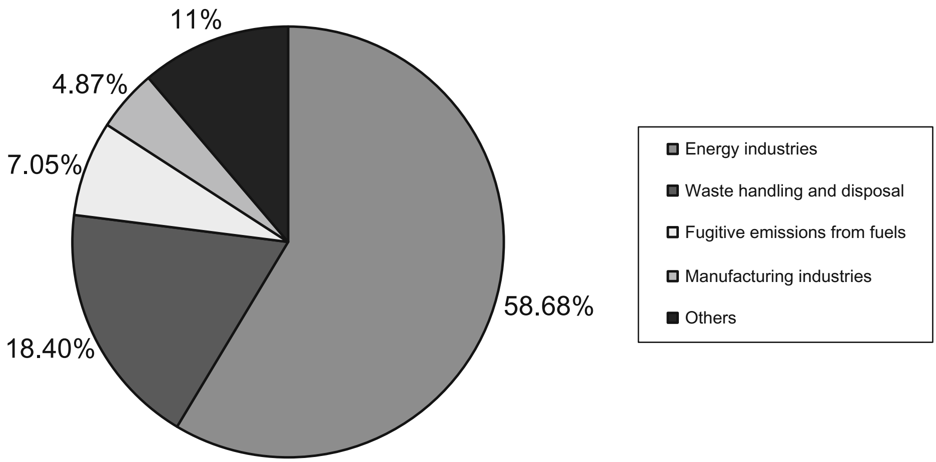

Fig. 1. Distribution of registered project activities by scope

refers to the secondary market credits. The price of secondary market CERs is usually higher than those that are bought directly from a project (primary CERs) because the entity takes all project risks (TFS Green 2008).

The distribution of registered project activities by scope (UNFCCC 2009) shows that projects involving energy industries (renewable and nonrenewable sources) will be the biggest in terms of number of projects (Fig. 1).

The market share of clean energy projects (renewable energy, fuel switching, and energy efficiency), in terms of volumes transacted, reached 82% in 2008 (World Bank 2009). Existing statistics show that industrial gases play an important role in the CDM markets, and, since 2003, HFC-23 and N_2O projects together have accounted for 50% of purchases, equating to about 480 $MtCO_2e$. However, the market share of HFC-23 continued to drop from its 2005 peak. The market share of coal mine methane projects was about 7% in 2006. Carbon credits derived from land use and land-use change and forestry (LULUCF) remained constant at 1% of volumes transacted in 2006. This could be due to their limitation of usage in the EU ETS (World Bank 2007).

Most of the CDM projects are currently being undertaken in Asia and South America. On the supply side, the market is dominated by China; its market share of transacted volume was about 83% in 2008, 73% in 2007, and 54% in 2006. Over the period 2002–2008, China accounted for about 66% of all contracted CDM supply in the market. After China, India and Brazil were second and third respectively in terms of 2008 transacted volume, at 4% and 3% market share, respectively. The supply of CERs could amount to 1.6 billion tCO_2e by 2012 (World Bank 2008).

European countries and their entities have significant effects on the CDM market through their demand either directly, by natural compliance buyers and the funds in which they are participants, or indirectly by entities planning to sell back these credits on the secondary markets. Their market share was over 80% in 2008. Private sectors such as entities from large energy utilities, power utilities, industrial manufacturing, oil and gas companies, banks, financial institutions, and investment funds across Europe may purchase CERs for compliance with Kyoto targets or to speculate on the market or for hedging and arbitrage purposes. These sectors continued to dominate the market in 2008 for the third consecutive year and they were the most active buyers, with 90% of the volume transacted in 2008. Within Europe, 59% of the market share in terms of volumes purchased has belonged to the UK, and London is still considered the carbon finance hub of the world (World Bank 2008).

Some large purchases by Japanese companies have been recorded in the World Bank confidential project database (World Bank 2008); its 2007 market share reached 11% from 6% in 2006. The amount allocated by the government of Japan to purchase at least 100 $MtCO_2e$ credits through 2008–2012 has been reported to be about US $815 million, or €490 million (World Bank 2008). The remaining industrialized Annex B governments have planned to buy about 20 $MtCO_2e$ from the Kyoto mechanisms. Moreover, it is expected that new demands for CERs from the USA (after the announcement of the Clean Energy and Security Act in May 2009), North America (after the Canadian announcement in late April 2007 to reduce its emissions and the California trading program following the enacted bill in California in August 2006), Australia (from compliance buyers covered by the Australian Carbon Pollution Reduction Scheme), and New Zealand will influence the CDM market significantly. The total demand for CDM and JI over the 2008–2012 period is estimated to be about 2.1 billion tCO_2e.

2.1 State of the CERs market

It seems the carbon market is increasingly seen as a central plank of the response to climate change. This corresponds to a transacted volume of carbon emissions rights, about 4.8 billion tCO_2e, which was valued at US $126.3 billion (€86 billion) in 2008 (World Bank 2009). The EU ETS continued to dominate the global carbon market, both in value and volume transacted. Its market share, in terms of 2008 transacted value was above 72% and in terms of 2008 transacted volume was about 64%. In 2008, about 3 billion tons of allowances were traded in this market, worth about €63 billion or US $92 billion, which is 87% more than the amount traded in 2007 (World Bank 2009). Table 1 reports the annual volumes and values for project-based transactions between 2005 and 2008.

According to Table 1, a strong interest in buying project-based credits has been observed in the carbon market and most of the project-based market activity has been done through the CDM market. The volume and the value transacted through the primary CDM projects were about 552 $MtCO_2e$ and US $7433 million in 2007 (World Bank 2008). However, the primary market was influenced considerably by financial crises and the value of transactions decreased by 12%

Table 1. Annual volumes and values for project-based transactions

Market type	2005		2006		2007		2008	
	Volume ($MtCO_2e$)	Value (MUS$)	Volume ($MtCO_2e$)	Value (MUS$)	Volume ($MtCO_2e$)	Value (MUS$)	Volume ($MtCO_2e$)	Value (MUS$)
Primary CDM	341	2417	537	5804	552	7433	389	6519
Secondary CDM	10	221	25	445	240	5451	1702	26277
JI	11	68	16	141	41	499	20	397
Voluntary market	6	44	14	70	43	263	54	397
Total	388	2937	611	6536	876	13646	1535	33487

Data from World Bank (2007, 2008, 2009)

$MtCO_2e$, million tonnes equivalents of CO_2; MUS$, million US dollars; CDM, Clean Development Mechanism; JI, joint implementation to US $6519 million in 2008 (see Table 1). In contrast, the secondary market for CERs has grown dramatically since the second half of 2006 (World Bank 2007) and it continued to grow exponentially in 2008. In 2008, a total volume of about 1072 $MtCO_2e$ secondary CERs was transacted for a total value of US $26.3 billion (€18 billion). The traded values and volumes experienced growth of more than 350% from 2007, representing the largest growth rates across all segments of the carbon market (World Bank 2009). This is because of the advantages for buyers who purchase a secondary market CER. For example, there is no risk of project performance on any one project and a secondary market CER can be considered as a near compliance-grade asset with firm volumes deliveries and guarantees.

Despite the economic downturn, demand for secondary CERs increased in 2008. The trade of CERs for different purposes such as compliance, hedging, and arbitrage has been facilitated by the increased standardization of contracts in the secondary market. This can increase the incentive for market participants to buy more CERs. Moreover, the needs of the industrialized Annex B countries to balance their carbon positions for their Kyoto Protocol commitments can increase the demand for CERs over the 2008–2012 period. The release of verified emissions data by the European Commission, which shows a resonable shortfall in allowancent in the EU ETS, could boost the CERs market because more buying is needed for some compliance buyers to close their positions for compliance. In addition, the adaptation of the Climate and Energy Package by the European Parliament strengthens and extends the EU ETS beyond 2012 and allows compliance buyers to bank EUAs and CERs from phase II to phase III. This could impact on the market by increasing the incentives of market participants to buy excess amounts of carbon rights and bank those for phase III with tougher targets and increased levels of auctioning and benchmarking[3]. In other words, it is expected that much of the shortfall of the EU ETS for phase II and III will be addressed through using CERs as cheap abatement measures. By taking into account the emerging new emissions trading schemes in countries such as the USA, Canada, Australia, and New Zealand, the demand for CERs may increase. This may strengthen the future role of the CDM in providing cost-effective GHG emission reduction options.

According to a Point Carbon report, in 2008 approximately US $100 billion (€70 billion) worth of EUAs and secondary CERs were traded in the European carbon market. For the year, the total transacted volume of EUAs, bought and sold, reached nearly above 3 billion tonnes. Furthermore, almost 400 million CERs were traded on Europe's carbon desks in 2008. The EUAs and secondary CERs had an average price of about €22.65 and €17.30, respectively, over 2008 (Point Carbon 2009a, b).

2.2 How to price CERs

CERs are priced based on the evaluation of a number of factors that affect the project and thereby the value of CERs. These factors impacting on the price of

[3] CERs can be banked from phase II to phase III but the EU rules and eligibility of project types seems to need further clarification.

CERs include EUA prices; credit that describes the financial positions of buyers and sellers, terms and conditions of the sale that explain delivery guarantees offered, the likelihood of generated volumes, the project validation and registration, the costs of the project design document, and who is supposed to pay; sovereign risk; stage of project development; quality risk; delivery risk; registration risk; and access to market (TFS Green 2008).

In contrast to the European allowance-based market, project-based markets experienced greater price stability in 2006 and 2007, although the early stage pricing of CERs occurred in a situation of uncertainty about the initial enforcement of the Kyoto Protocol. For example, early trades of CERs occurred with an average price between US $4 and US $6. However, in 2006 the weighted average price for primary CERs was about US $10.90 per tCO_2, which was a 52% growth over its level in 2005 and slightly lower than the US $11.10 observed in the first quarter of 2006 (World Bank 2007). The average contracted price was about US $13.60 (€9.90) and US $16.78 (€11.46) in 2007 and 2008, respectively. The lowest price for a CER was about US $6.80 in 2006, which was about 172% higher than the lowest price paid for a CER in 2005, US $2.5. In 2007, the minimum price for CERs rose to US $9 (€6.5), up 32% from 2006 (World Bank 2008).

Currently, it seems that having a benchmark for CER pricing is preferred by both buyers and sellers, and informal Chinese policy, which requires a minimum acceptable price before providing Designated National Authority (DNA) approval to projects, as a dominant force in the supply side of the CDM markets, has significant influence on the price of CERs. This minimum or floor price ranges between €8 and €9 (World Bank 2008). Moreover, the observed price on the secondary market has been reported as the other main market benchmark for CER pricing.

Existing statistics show that the price of issued CERs and a secondary market guaranteed CERs were observed at around 80% of the price of EUA-08 and were higher than the price of primary CERs (World Bank 2008). However, during the financial meltdown the discount ranged from between €1 and €8. The range at which secondary CERs were transacted in 2006 was between US $10.75 and US $27 (World Bank 2007). In 2007, the December 2008 guaranteed CERs were traded at a price of €16–18, which is about 75%–80% of the December 2008 EUA price. It is expected that the price of secondary CERs will experience an upward trend because of greater regulatory certainty for noncompliance in an emissions trading scheme, the linking directive under the EU ETS, and emerging new emission trading schemes, which will lead to an increase in demand for CERs[4]. The following graph shows the price spread between EUA and CER prices.

[4] However, the European commission's recent package (Climate and Energy Package) for phase III under the EU ETS, which imposes a tight limit on the availability of CERs (EU 2009), and any changes in rules of eligibility of EU companies in favor of using assigned amount units can impact on CER prices.

As illustrated by the above graph, there is a price differential between the EUA and the CER. This price spread can be attributed to different market frameworks and institutional events, different risk attitudes, different levels of certainty, different decision-making mechanisms of market participants, and some variables stemming from the market microstructure literature. For example, the CER price is influenced on the supply side by the decisions of the CDM Executive Board, which decides on the delivery rules, and on the demand side by the industrialized countries, which determine the institutional fungibility of CERs within their emissions trading schemes. Moreover, CERs can be demanded by industrialized governments that are directly fulfilling their compliance with the Kyoto Protocol, such as Japan. In other words, a price differential can be attributed to a number of factors such as a cap on the number of CERs emanating from supplementarity issue, some lack of clarity regarding the use and the import of project-based credits (including swapping and banking), concerns regarding the issue of the contractual provisions for the delivery of secondary CERs (delivery risk), risk perceptions,[5] size of the gap between the business-as-usual emissions and the level of allowances, economic growth, fuel energy prices, weather conditions, and concern regarding the operation of the Community Independent Transaction Log (CITL) and the International Transaction Log (ITL). Because there are two different market frameworks, carbon market drivers could impact on CER and EUA prices in different ways, which may be reflected in the price spread.

Because European buyers are the most active players in the CDM market and perhaps account for the largest source of demand on the secondary CER market, communications of the European Commission concerning changes in the import limit of CERs should be considered when investigating the price spread. Imposing any restrictions on the use and availability of CDM credits within Europe due to supplementarity and additionality regulations would impact significantly on the CDM market and thereby on the CER prices. So despite the existence of a guaranteed delivery for the secondary market, the price spread between the secondary guaranteed CER and future EUA prices can be primarily attributed to these restrictions and the delivery risk, which causes some limitations and delay in order to deliver and transfer CERs across national registries (World Bank 2007).

The price spread between secondary CERs and EUAs was about €6–7, but it widened to nearly €10 in January 2008. This was due to a reaction to the European Commission's proposal for a phase III, which limits the availability of project-based credits up to 1400 MtCO_2e until 2020[6] for its member states and their operators. Under this scenario, no global agreement would be achieved in the

[5] Contracting project-based credits involve higher transaction costs and more risk than purchasing EUAs because an EUA is a definite property right issued by the government of an EU member state. However, secondary CERs are credit underwritten by investment banks.
[6] It has increased to 1700 MtCO_2e after the adaptation of the Climate and Energy Package in December 2008.

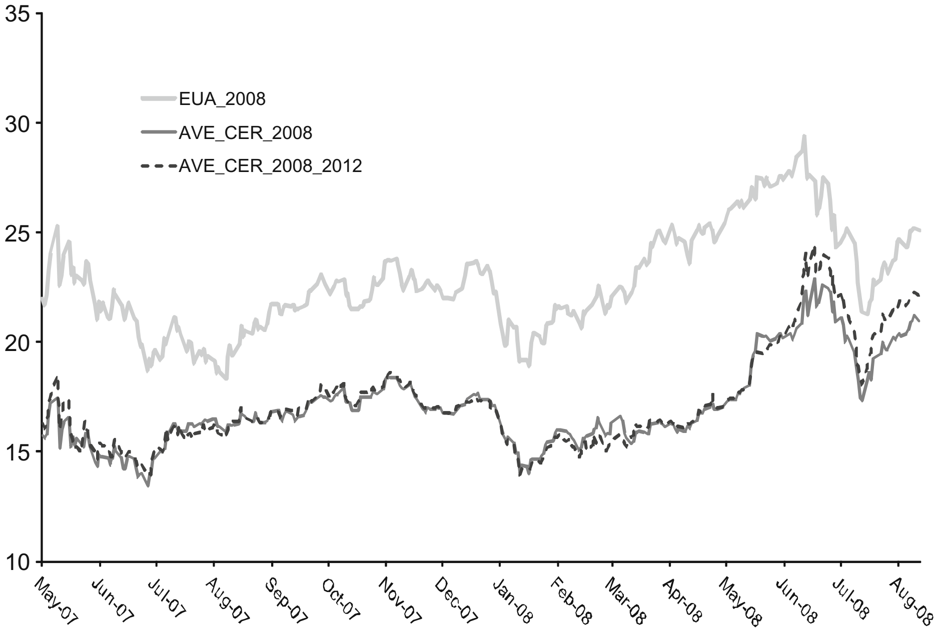

Fig. 2. The price spread between European allowances (EUAs) and certified emission reductions (CERs)

post-Kyoto period (World Bank 2008). However, as prices for EUAs delivered in 2008 began to drop in the second half of 2008, the price spread narrowed (see Fig. 2).

As mentioned earlier, from a theoretical point of view it is expected that by linking the EU ETS to the CDM, the EUA prices will go down. However, the extent of the decline in prices can be influenced significantly by regulations and restrictions emanating from the supplementarity issue and the risk associated with the CERs. In the following, some of the existing regulatory restrictions on the usage of project-based credits in the European community are reported.

2.3 The EU ETS rules

One of the policy tools the European Union has designed to contribute to fulfilling the commitments of the community and its member states to reduce anthropogenic greenhouse gas emissions under the Kyoto Protocol at the most cost-effective way is to establish a link between the EU ETS and the CDM. So on 23 July 2003, the European Commission decided to link the CDM and JI mechanisms with the ETS, which took the form of an amendment to the ETS-Directive (European Commission 2006). It allows for the conversion of CERs and ERUs into EUAs for use in the EU ETS from 1 January 2008 onward

(Lefevere 2005). According to Article 11 of EU Amendments to Directive, 2004, "Member states may allow operators to use CERs from project activities in the community scheme and all CERs that are issued in accordance with the UNFCC and the Kyoto Protocol may be used in the community scheme" (EU 2004). The advantage of this inclusion could be the reduction of the compliance costs for the sectors covered under the EU ETS by increasing the cost-effective reduction options.

According to the Kyoto Protocol, Article 6.1.d, "the acquisition of emission reduction credits shall be supplemental to domestic actions for the purposes of meeting commitments under article 3," but no quantitative limit has been defined for that in the Marrakech accords. Therefore, the European Union imposed some limits on the quality and on the maximal amount of JI/CDM credits that each covered installation is entitled to use for compliance under the scheme. This was executed in an attempt to quantify the supplementarity criterion and due to the fact that the EU ETS is designed as a key policy tool to reduce emissions from the domestic industry sector. For example, it states that the member state cannot use more than 50% of its reduction commitment through importing credits from the project-based mechanisms in order to meet its target (Langrock and Sterk 2004).

Apart from the supplementarity issue under the Kyoto Protocol, which limits government trading, there is another supplementarity issue under the European Union, which limits installation-based trading. According to the EU amending directive, "Member states may allow operators to use, in the community scheme, CERs from 2005 and ERUs from 2008 and the use of CERs and ERUs by operators may be allowed up to a percentage of the allocation of allowances to each installation, to be specified by each member state in its national allocation plan for that period," (EU 2004). Moreover, the European Commission (2006) states that "EU ETS installations in that member state would only be able to use JI/CDM credits up to a level of less than 10%, the Commission considers that as a minimum threshold installations should be allowed to use JI/CDM credits up to a level of 10%." In other words, the Commission will assess consistency with supplementarity obligations based on an import limit of 10% of a member state's assigned emission cap. For example, in the UK, operators are allowed to use CERs or ERUs up to 8% of its annual allowance surrender in phase II (Shaw 2007).

Currently, member states and all installations covered by the EU ETS are allowed to use CERs[7] to fulfill their EU Kyoto targets. At the moment, the EU ETS only covers energy-intensive installations such as electricity generation, paper production, metals production installations, and the mineral industry, which emit more than 45% of the European CO_2 emissions. According to the EU Linking Directive, the installations subject to the ETS are allowed to use CERs, but governments can place some restrictions on the use of CERs by them

[7] There are two exceptions: CERs from nuclear facilities and sink projects.

to meet the supplementarity issue. In the following section, the European legal framework on the import and use of CERs within the EU ETS for phase II are reported.

2.4 Phase II

The European Commission completed the National Allocation Plans (NAPs) for the 27 member states in early October 2007. The Commission aimed to ensure that the EU ETS phase II is short. Accordingly, a maximum of 2098 million EUAs (per year) is the allowed cap for total EU and EEA, European Economic Area, (EU 2008). The Commission decided to restrict the use of project-based credits in the second trading period and the guidance for this restriction is based on the interpretation of criterion 12 of Annex III (EU 2004). According to this criterion, the total number of credits that are allowed to be imported by each member state is determined by a formula, and it describes the rules that member states should consider when fixing the limit on the use of the Kyoto credits for the installations covered by the ETS. The criterion also sets a threshold (a minimum percentage) on the number of project-based credits that any installation is allowed to use.

The Commission states that the maximum number of project-based credits that member states are allowed to use depends upon the "reduction effort" they have to make to meet their EU Kyoto targets (European Commission 2006). This reduction effort can be calculated based on the three different baselines of 1990, 2004, and 2010. Moreover, the maximum amount of CER and ERU that a member state is allowed to use is equal to half the highest difference between the level of GHG emissions in one of these years and the reduction target laid down in the Burden-Sharing Agreement and the Kyoto Protocol[8] (European Commission 2006). This formula set an effective ceiling of 50% on the number of the Kyoto credits to be used by a member state with respect to their reduction effort. If member states purchase project-based credits, they are required to deduct the number of JI/CDM credits from the overall number to be used by the operator subject to the EU ETS. On the contrary, if they do not purchase any credits with government funds, the full number of credits can be distributed among the installation covered by the EU ETS. Member states have to determine the maximum number of credits that operators covered by the ETS are allowed to use as a percentage of the allowance allocation to each installation (De Sepibus 2008). Moreover, the limit imposed on the use of project-based credits by the operator cannot be less than 10% of their allowance allocation (European Commission 2006).

The aggregate limit on the use of JI/CDM within the EU ETS amounts to 13.4% of the overall cap, which means the maximum demand for Kyoto mecha-

[8] Under the Kyoto Protocol, the EU committed to reduce its emissions by 8% below its 1990 levels over the 2008–2012 period. The EU redistributed the target among its member states in a burden-sharing agreement, and each member state has to meet the specific target set by this agreement.

nism's credits would be up to 278.3 million tCO_2 per year in phase II (World Bank 2008). In other words, the maximum allowable utilization of CERs and the ERUs during phase II is 1400 $MtCO_2$.

During phase II, member states can auction up to 10% of their allowances. Moreover, EUAs from phase II onward to future compliance periods can be banked (World Bank 2009). The Commission addressed the issue of banking the EUAs and CERs to prevent the effects of possible over allocation, which can lead to a dramatic drop in carbon prices in the second trading period.

It is believed that linking the EU ETS to the CDM allows European companies to reduce the cost of European Kyoto compliance through increasing the diversity of low-cost options within the community. In other words, it is expected that the European traders mainly use the CDM markets to address their shortfall of EU allowances under the EU ETS for phase II and this can increase their cost effectiveness in achieving the emissions reductions. This corresponds with the fact that the secondary CERs market is the second-largest segment in the carbon market with more than a 350% increase in traded values and volumes over the previous year.

The CDM is considered a vital part of the Kyoto Protocol to provide cost-effective GHG emission reduction options. This is despite policy-driven regulations that restrict the use and availability of CERs emanating from the additionality and supplementarity criteria, which can impact on the efficiency gains from project-based credits. The following factors could also strengthen the CDM market's role in reducing emissions in an economically efficient way during the Kyoto Protocol commitment period and beyond: the need of the industrialized Annex B countries (by both governments and private sectors) to balance their carbon positions for their Kyoto Protocol commitments in 2008–2012 (notably the EU and Japan); the usability and bankability of CERs for the post-Kyoto period in phase III under the EU ETS; the increasing interest in CERs for voluntary offsetting purposes; and the potential demand for CERs as a result of emerging new emissions trading schemes in some countries such as the USA, Canada, Australia, New Zealand, and Switzerland, which will directly impact on the CDM market by increasing the incentive for market participants to buy excess CERs. However, the CERs access restrictions for installations play important roles on how linking to the CDM can impact on emissions trading schemes. In the following section, the price impacts of linking the EU ETS to the CDM are investigated.

3 Econometric model and preliminary data analysis

The models presented in this article are empirically estimated based on daily data from the 25 May 2007 to 1 September 2008. The December 2008 delivery EUA price, the secondary market CER 2008 (bid and offer), the secondary market CER 2008–2012 (bid and offer) have been extracted from Point Carbon Website. All prices are quoted in euros per tCO_2 and all variables are expressed as logarithms. Only empirical results are reported, which are based on the average bid and offer prices for secondary market CER in the following tables, although the interaction between variables are investigated for bid and offer prices separately.

Because the order of integration of a time series is very important for analyzing the economic time series, part of this section is dedicated to investigate the existence of a unit root in the selected price series. Then cointegration tests are performed on all price series. In order to investigate temporal interactions among the variables, a Granger causality test and impulse response analysis are used.

3.1 Unit root tests

The augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (Kwiatkowski et al. 1992) tests are statistical tests that were chosen to investigate the integration properties of the series. The results of the ADF and KPSS tests for both the logarithm series on levels and the first differences are presented in Table 2.

The conclusion from the ADF tests is clear: at the 1% level the unit root hypothesis cannot be rejected for all series on levels. The KPSS test confirms the result. It clearly rejects the stationary hypothesis at the 1% level for all series in levels. Moreover, these tests support the stationary hypothesis for the first differences of all series. Thus, the appropriate tests support the conclusion that the series may be treated as I(1) and specifying a stationary model for the first differences seems appropriate.

Table 2. Unit root tests

Variables	ADF test	KPSS test
Variables in (log) levels		
EU_2008	–1.87	1.12***
CER_08_12_Bid	–1.00	0.99***
CER_08_12_Offer	–0.96	0.96***
CER_08_Bid	–1.28	1.04***
CER_08_Offer	–1.33	1.00***
AVE_CER_08_12	–0.93	0.97***
AVE_CER_08	–1.26	1.02***
Variables in log differences		
EU_2008	–18.09***	0.05
CER_08_12_Bid	–18.75***	0.11
CER_08_12_Offer	–18.90***	0.13
CER_08_Bid	–18.60***	0.08
CER_08_Offer	–19.66***	0.08
AVE_CER_08_12	–18.44***	0.14
AVE_CER_08	–18.83***	0.09

ADF, augmented Dickey-Fuller; KPSS, Kwiatkowski, Phillips, Schmidt, and Shin

*** Statistical significance at 1% level. Tests are performed for variables in levels with optimal lag lengths chosen by SIC (Schwarz information criterion) criteria

3.2 The Granger causality test

This study uses time-series econometric techniques to test for the existence of long-term links and causal relationships between the EUA and CER prices. This work started by investigating the unit root of the series; the next step is then to investigate possible cointegration relations between the selected price series to specify appropriate models. In this article, testing for cointegration in a vector autoregression (VAR) model is done by using maximum-likelihood cointegration tests provided by Johansen (Johansen 1991, 1988). According to the cointegration tests (the Trace statistic), there is very strong evidence for a cointegration rank of zero.[9] In other words, the two variables (EUA'08 and different secondary CER prices) in each of the systems do not appear to be cointegrated.

The next step in the analysis is to specify appropriate models. On the basis of the unit root and cointegration analysis results, it seems that the application of an unrestricted VAR in first differences is appropriate to investigate temporal interactions between the variables. Therefore, this study models price series on the first logarithm differences in unrestricted VAR models with sufficiently long optimal lag lengths (chosen by the Akaike information criterion, the final production error, and Hannan-Quinn information criterion) to ensure absence of autocorrelation. After estimating the models, Granger causal relations between variables can be investigated. Testing for Granger causality needs checking if specific coefficients are zero, so the standard tests for zero restrictions on VAR coefficients (Wald tests) can be used here (Lütkepohl and Kratzig 2004).

Tests for causality based on VAR(1) models in first differences are given in Tables 3 and 4. In Table 3, none of the *P* values are smaller than 0.05. Hence, using a 5% significance level, none of the noncausality null hypotheses can be rejected. In other words, on the basis of these tests no causal relations from CERs to EUAs prices can be diagnosed with any certainty. These results show that the CER prices do not have Granger causality effects on EUA prices.[10]

According to Table 4, there is, however, strong evidence of a Granger causal relation from EUA 2008 prices to CER 2008–2012 prices because the *P* value of

Table 3. Tests for causality from certified emission reduction (CER) to European allowance (EUA) prices based on the VAR(1) models in first differences

CER prices	EUA_2008[a]	
	χ^2 test value	*P*
AVE_CER_2008	0.00	0.96
AVE_CER_2008_2012	0.14	0.70

All variables are first log differences
[a] Dependant variable

[9] The results are quite similar in favor of no cointegration regardless of considering trend, constant, and different number of lags.
[10] The results are the same once offer and bid prices are considered separately.

Table 4. Tests for causality from EUA to CER prices based on the VAR(1) models in first differences

EUA price	AVE_CER_2008[a]		AVE_CER_2008_2012[a]	
	χ^2 test value	P	χ^2 test value	P
EUA_2008	1.22	0.26	5.48	0.01

All variables are first log differences
[a] Dependant variable

the related test is less than 5%.[11] Based on these results, one would expect that it is the EUA prices that drive the secondary market CER prices.

Moreover, in order to investigate the temporal interaction between these prices, the VAR is estimated in levels and tested for Granger causality. If the VAR contains I(1) variables, standard tests for zero restrictions on VAR coefficients may have nonstandard asymptotic properties (Lütkepohl and Kratzig 2004). These problems can be removed by fitting a VAR with an order that exceeds the true order and by ignoring the extra parameters in testing for Granger causality (Dolado and Lütkepohl 1996; Toda and Yamamoto 1995). This means the singularity problem can be removed by overfitting the VAR order; use of VAR ($\rho + 1$) instead of a VAR (ρ) process and the Granger causality test can be performed on the A_i, $i = 1 \ldots \rho$.

The results of Granger causality tests based on VAR models in levels are quite similar to what has been found based on VAR models in first differences. On the basis of these tests, using a 5% significance level, no causal relations from CER to EUA prices can be diagnosed. However, there is strong evidence of a Granger causal relation from EUA 2008 to CER 2008–2012 prices.

The statistical evidence does not support any strong substitution effects of CER for EUA and the major factor for this can be access constraints on CERs, which would limit their ability to cause any significant effects on the EUA prices. Other factors such as generous allocation of allowances to the ETS sectors, the determination of EUA prices in a more mature and established market, and nontransparency of the CDM market and its post-2012 uncertainty can also be attributed to this finding, which is discussed in the concluding section.

3.3 Impulse response analysis

In order to analyze the dynamic interaction between the EUA and the CER prices, an impulse response function was used. These models have a reduced-form status, so the generalized impulse response analysis could be an appropriate method to investigate the dynamic interaction. The method is not sensitive to

[11] There is also weak evidence of a Granger causal relation from EUA 2008 to CER 2008 offer prices, because the P value is less than 10%. There is strong evidence of Granger causal relations from EUA 2008 to either CER 2008–2012 bid or CER 2008–2012 offer.

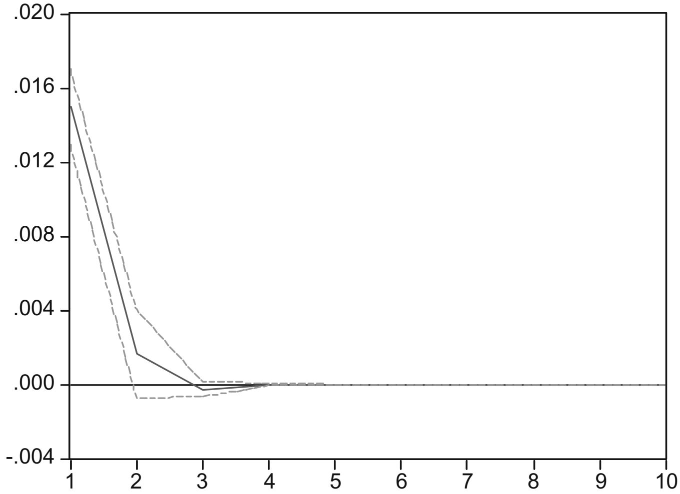

Fig. 3. Response of CER price to an EUA price shock

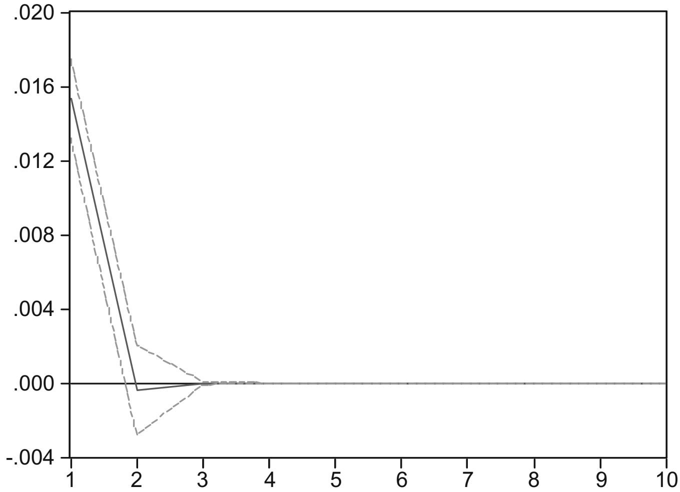

Fig. 4. Response of EUA price to a CER price shock

the order in which the variables are entered to the VAR and it requires no identifying restrictions (Pesaran and Shin 1998).

Figures 3 and 4 show the impulse response functions based on the VAR(1) models in first differences. The response standard errors are computed based on analytic (asymptotic) standard errors.

According to the estimated VAR models and considering the standard error bands, the estimated dynamic impact of one standard deviation change in European allowance price has a significant positive effect on the CER prices for about 2 days. In other words, a positive shock to EUA price increases the CER price for about 2 days before it returns to its initial level. The interval estimate indicates that the European allowance price does not react significantly to a positive shock to the CER price and it dies immediately after the shock has occurred.[12]

4 Conclusions

Most countries are considering a CDM as a helpful tool in scaling up their efforts to reduce greenhouse gas emissions while growing their economies. Because it is believed that developing countries can deliver a large cost-effective emission abatement, the CDM's biggest strength is its ability to engage developed and developing countries to contribute meaningfully to climate change mitigation and lessen global emissions in the most cost-effective way. As a result, one of the policy tools designed by the EU to fulfill its compliance requirements is to establish a link between the EU ETS and the CDM. From a theoretical point of view, having access to the Kyoto project-based mechanisms can lead to some cost saving in meeting the EU Kyoto target through increasing the compliance options within the Community, using cheap project-based credits by operators, and decreasing the European allowance prices. In other words, economic theory suggests that linking the EU ETS to the CDM and the indication of recognizing CERs as equivalent to EUAs will drive down EUA prices, and, in turn, lead to a reduction of the overall EU compliance costs. However, the expected effects and, more specifically, the extent of the decline in EUA prices can be influenced significantly by the CER access restrictions in the EU emanating from the supplementarity and additionality criteria stipulated by Kyoto.

This article provides an analysis of the relationship between the EU ETS and the CDM. In particular, it measures the price effects of this link by focusing on the dynamic interaction between the European allowance prices and CER prices. Time series econometric techniques have been employed to investigate the relationship between these prices. More specifically, in order to test the temporal interaction between these variables, the VAR models have been specified (based on results from unit root and cointegration tests) and Granger causality tests as well as generalized impulse response analysis have been used.

The results show, based on the estimated VAR models, that CER prices do not have a statistically significant effect on EUA prices during the period investigated. In other words, the statistical evidence suggests that the changes in CER prices do not cause statistically significant changes in the European allowance prices. However, there is strong evidence of a causal relation from EUA to secondary CER prices and it appears that the EUA price drives secondary CER

[12] The results are based on the VAR(1) in first differences once the average price of CER 2008–2012 has been chosen. The findings are quite similar based on the VAR models in first differences for different CER price series.

price during the period investigated. There seems to be a desire for pricing of CERs to be based on the EUA prices, especially from European buyers who, as the most active buyers, prefer to tie the value of CER to the EUA price as the most established trading system for emission allowances.

The analyses suggest that the dynamics of EUA prices are currently independent of the price of CERs for this period. A number of factors can be hypothesized to account for this finding. First, it is believed that emissions allowance allocations to European energy-intensive industries were very generous in phase I (Anger 2008), and this implied that a low level of effort would be required for them to reduce their emissions. Moreover, the policy constraints on the use and the availability of CERs in order to quantify the supplementarity issue may limit the ability to substitute project-based credits. This means the CERs cannot serve as equivalent substitutes for EUAs and their impacts on permit prices cannot be as significant as expected.

In addition, the EUA prices are determined in the EU ETS, which is the most established market for greenhouse gas emission allowances; it dominates the global carbon market, both in transactions and monetary value (World Bank 2008). In comparison, the secondary CERs market, despite its exponential growth, is a relatively new market. Implementing the CDM project cycle (including project design, national approval, validation/registration, project financing, monitoring, verification, and issuance of CERs) can ensure that the projects result in real and measurable climate change benefits and meet the additionality criteria, while also reducing the quality and delivery risks. However, the implementation also raises some concerns that impact on the attractiveness of CERs as cheap options for compliance buyers. In other words, concerns regarding issues such as the CDM's procedural inefficiency (too many projects await registration and issuance), its additionality and sustainability (too many complex rules that are changed too often), and its uncertainty about the long-term future of the CDM market and its role post-Kyoto could result in CDM market failures. Such failures would limit the ability of the CDM to cause any significant impact on the EU ETS and thereby on EUA prices. The CDM Executive Board, by providing a reasonable degree of regulatory certainty, can enhance the credibility of the CER market and project participants' confidence.

In conclusion, it appears that the CDM remains a valuable tool in a climate regime and CERs are considered as important substitutes for carbon allowances by industrialized countries and their operators to meet their Kyoto obligations. It corresponds to this fact that the secondary CERs market was the second-largest segment of the global carbon market in 2008 with a fivefold increase in both value and volume over 2007. The future role of the CDM in reducing CO_2 emissions is expected to be strengthened in light of a number of factors: the need of the industrialized Annex B countries (by both governments and private sectors) to balance their carbon positions for their Kyoto Protocol commitments in 2008–2012 (notably the EU and Japan); the abilities to use and bank CERs for post-Kyoto in phase III under the EU ETS; and the demand for CERs as a result of emerging new emissions trading schemes in countries such as the USA, Canada, Australia, New Zealand, and Switzerland. However, the question of how to link EU emissions allowance trading with the CDM to provide more flexibility and improved cost effectiveness in reducing emissions depends upon who is allowed to use CERs and under what circumstances is of fundamental importance to the market. The author believes that the future role of the CDM market (in reducing GHG emissions in an economically efficient way) and its environmental credibility during the Kyoto period and beyond can be strengthened by reducing access restrictions on the use and availability of CERs that can impact on the efficiency gains from project-based credits. In other words, a more efficient climate policy to reduce the costs of the European emission mitigation strategies would be to provide unlimited use of the project-based credits for both operators and member states. Limiting the availability of project-based credits can impact significantly on the efficiency of this link. Moreover, as European operators are the world's biggest buyers of CERs, the EU has a major say in how the CDM market will operate in a future climate deal and any plan by the European Commission can impact the global carbon market remarkably.

References

Ahman M, Burtraw D, Kruger JA, Zetterberg L (2007) The ten-year rule-allocation of emissions allowances in the EU emissions trading system. Energy Policy 35:1718–1730

Alberola E, Chevallier J, Cheze B (2008) Price drivers and structural breaks in European carbon prices 2005–07. Energy Policy 36:787–797

Anger N (2008) Emissions trading beyond Europe: linking schemes in a post-Kyoto world. Energy Economics 30:2028–2049

Anger N, Bohringer C, Moslener U (2007) Macroeconomic impacts of the CDM: the role of investment barriers and regulations. ZEW discussion paper No. 07–026, Mannheim

Benz E, Trück S (2009) Modelling the price dynamic of CO2 emission allowances. Energy Economics 31:4–15

Betz R, Rogge K, Schleich J (2006) EU emissions trading: an early analysis of national allocation plans for 2008–2012. Climate Policy 6:361–394

Böhringer C, Hoffmann T, Manrique-De-Lara-Penate C (2006) The efficiency costs of separating carbon markets under the EU emissions trading scheme: a quantitative assessment for Germany. Energy Economics 28:44–61

Christiansen AC, Wettestad J (2003) The EU as a frontrunner on greenhouse gas emissions trading: how did it happen and will the EU succeed. Climate Policy 3:3–18

Convery FJ (2009) Reflections—the emerging literature on emissions trading in Europe. Review of Environmental Economics and Policy 3:121–137

Criqui P, Kitous A (2003) Impacts of linking JI and CDM credits to the EU ETS. Kyoto Protocol Implementation, KPI. Technical Report, B4–3040/2001/330760/MAR/E1

De Sepibus J (2008) Linking the EU emissions trading scheme to JI, CDM and post-2012 international offsets. NCCR Trade Regulation, Working paper no. 2008/18

Dickey DA, Fuller WA (1979) Estimation for autoregressive time series with a unit root. Journal of the American Statistical Association 74:427–431

Dolado JJ, Lütkepohl H (1996) Making Wald tests work for cointegrated VAR systems. Econometric Reviews 15:369–386

European Commission (2003) Proposal for a directive of the European Parliament and of the council amending the directive establishing a scheme for greenhouse gas emission allowance trading within the community, in respect of the Kyoto Protocol's project mechanisms, COM (2003) 403

European Commission (2006) Communication from the commission to the council and the European Parliament on the assessment of national plans for the allocation of greenhouse gas emission allow-

ances in the second period of the EU ETS accompanying commission decisions of 29 November 2006 on the national allocation plans of Germany etc., COM (2006) 725
European Union (EU) (2003) Directive 2003/87/EC of the European Parliament and of the council of 13 October 2003 establishing a scheme for trading in greenhouse gas emission allowances within the community and amending Council Directive 96/61/EC. European Commission, Brussels
EU (2004) Directive 2004/101/EC, amending directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the community, in respect to Kyoto Protocol's project mechanisms. European Commission, Brussels. http://eur-Lex.europa.eu/LexUriServ/site/en/oj/2004/1_338/1_33820041113en00180023.pdf. Cited
EU (2008) Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008. Official Journal of the European Union
EU (2009) Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009. Official Journal of the European Union
Johansen S (1988) Statistical analysis of cointegration vector. Journal of Economic Dynamics and Control 12:231–254
Johansen S (1991) Estimation and hypothesis testing of cointegration vector in Gaussian vector autoregressive models. Econometrica 59:1551–1581
Jotzo F, Michaelowa A (2002) Estimating the CDM market under the Marrakech accords. Climate Policy 2:179–196
Klepper G, Peterson S (2006) Emissions trading, CDM, JI, and more: the climate strategy of the EU. Energy Journal 27:1–26
Kwiatkowski D, Philips PCB, Schmidt P, Shin Y (1992) Testing the null of stationary against the alternative of a unit root: how sure are we that the economic time series have a unit root? Journal of Econometrics 54:159–178
Langrock T, Sterk W (2004) The supplementarity challenge: CDM, JI and EU emissions trading. Policy Paper 1/2004. Wuppertal Institute for Climate, Environment and Energy, Wuppertal
Lefevere J (2005) Linking emission trading scheme: the EU ETS and the linking directive. Oxford University Press, Oxford
Lütkepohl H, Kratzig M (2004) Applied time series econometrics. Cambridge University Press, Cambridge
Michaelowa A, Stronzik M, Eckermann F, Hunt A (2003) Transaction costs of the Kyoto mechanisms. Climate Policy 3:261–278
Pesaran H, Shin Y (1998) Generalized impulse response analysis in linear multivariate models. Economic Letters 58:17–29
Point Carbon (2009a) Carbon shrugs off gas shortage concern. Point Carbon News. Carbon Market Europe. 8(1), 9 January
Point Carbon (2009b) European commission unveils post-2012 vision. Point Carbon News. Carbon Market Europe. 8(4), 30 January
Shaw D (2007) How projects from beyond the EU will affect carbon trading. Kyoto Energy. http://www.kyotoenergy.net. Accessed 28 Aug 2008
TFS Green (2008) Clean Development Mechanism. TFS Green part of tradition. http://www.tfsgreen.com/global-markets/clean-development-mechanism/. Accessed 11 Aug 2008
Toda HY, Yamamoto T (1995) Statistical inference in vector autoregressive with possibly integrated processes. Journal of Econometrics 66:225–250
United Nations Environment Programme (UNEP) (2004) CDM information and guidebook (2nd edn). United Nations Environment Programme, Roskilde, Denmark
United Nations Framework Convention on Climate Change (UNFCCC) (1997) Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations Framework Convention on Climate Change, FCCC/CP/L.7/Add1, Kyoto
UNFCCC (2002) Report of the conference of the parties on its seventh session. 29 Oct–10 Nov, 2001, Marrakesh. http://unfcc.int/resource/docs/cop7/13.pdf. Accessed 14 Feb 2008
UNFCCC (2009) CDM statistics. United Nations Framework Convention on Climate Change. http://ghg.unfccc.int. Cited
Weitzman M (1974) Prices vs. quantities. Review of Economic Studies 61:477–491
Weyant JP, Hill JN (1999) Introduction and overview. Energy Journal, special issue on the costs of the Kyoto Protocol: A multi-model evaluation, pp 7–44

World Bank (2007) State and trends of the carbon market 2007. World Bank Report, Washington DC
World Bank (2008) State and trends of the carbon market 2008. World Bank Report, Washington DC
World Bank (2009) State and trends of the carbon market 2009. World Bank Report, Washington DC