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Abstract

The Kyoto Clean Development Mechanism (CDM) is the first "global" and largest carbon offset instrument, supplementing national or regional cap and trade systems such as the European Union's Emission Trading Scheme (EU ETS). This paper draws on weekly IDEACarbon survey data from 2008 to 2010 to empirically examine how investor's perception of the CDM regulatory and administrative framework affects the price of CERs in secondary markets (denoted as sCER) and the price spread with EUAs. Results from cointegration analysis and GARCH modeling indicate that the perception of investors about the relative stringency and efficiency of this framework is a significant determinant of the sCER price and the EUA-sCER price spread. An increase in perceived stringency causes significant increases in sCER prices and a substantial narrowing of the EUA/sCER price spread (and vise versa). The analysis also shows that the EU ETS market was instable over the period examined, with a structural shift occurring at the end of 2008 likely due to the 2008 financial crisis.

JEL Classification: Q56, Q68,
Keywords: emission permits, EUA-sCER Spread, spot and future price dynamics, carbon derivatives

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1 Introduction

The Clean Development Mechanism (CDM) established under the Kyoto Protocol has two primary objectives: to promote clean development in non-Annex I countries, typically developing countries; and to assist Annex I (developed) countries in achieving their Greenhouse Gas (GHG) reduction commitments through cost-effective clean production investments in non-Annex I countries (IPCC, 2007). Certified Emission Reduction units (CERs) generated from CDM projects can be used by Annex I countries to help comply with their emission reduction targets, supplementing thereby their Emission Reduction Units (ERUs) certified by a Joint Implementation Supervisory Committee. By 2012, the end of the Kyoto commitment period, the CDM is expected to account for about 1.2 billion tons of carbon dioxide equivalent (CO_2e) in emission reductions in non-Annex I countries (World Bank, 2010).

The European Union Emission Trading Scheme (EU ETS) is the largest source of demand for CERs; other sources of demand include Japan, Canada and private entities under regional cap and trade regimes in the United States. While there is a linking mechanism between the EU ETS and the Kyoto Protocol, European Union Allowance (EUA) units under the EU ETS are only partially substitutable by CERs due to caps limiting the degree of substitutability (Flam, 2009).[1] Although both Certified Emission Reduction (CER) units issued under the CDM and European Union Allowance (EUA) units issued under the EU ETS represent the right to emit one ton of CO_2 in the atmosphere, CERs

[1] On average, during 2008 to 2010 the limit on CERs as a substitute for EUAs was 13 %. At the firm level, the fungibility between the EUA and the CER will depend on the regulated installation's location and industry, as the CER import cap varies across countries.

trade at a discount to EUAs in secondary markets (denoted as sCERs). The partial fungibility between CERs and EUAs and other regulatory uncertainties, including the future role of CERs in the EU ETS and delays related to transferring CERs into national climate registries, are contributing factors for the discount.

More recently, the recession and the Eurozone crisis, combined with lack of consensus of the worlds' major economies to continue the Kyoto protocol, have been driving down the demand for EURs and sCERs. This has led to the decline of the trading price of sCERs from highs around $20 before the financial crisis to less than $1 in October 2012. In response, the European Commission presented proposals to regulate the phase III supply of EUAs to be auctioned, in order to support the carbon price and restore operators' confidence. In the case of sCERs, the situation is further complicated by use restrictions on credits from HFC-23 and N2O projects[2]. The future role of the CDM in carbon trading is uncertain in light of the virtual collapse of CER market prices.

Yet, there is much to be learned from the 10-year history of the CDM, which attracted billons of euros of private capital on an annual basis. Apart from channeling funds to developing world for clean development, the CDM is the largest offset instrument, complete with functioning frameworks and standards for the issuance and trading of credits for GHG reduction. In the event that governments decide to strengthen their collection action to reduce GHG emissions, lessons learned from the

[2] On 25 November 2010, the European Commissioner for Climate Action announced a proposal to prohibit use of EURs and CERs from projects involving the destruction of hydrofluorocarbon 23 (HFC-23) and nitrous oxid (NxO) in the EU ETS from 1 January 2013.

CDM experience will be useful in reforming the CDM and developing other market instruments.

Emissions trading schemes (ETS) appear to be a preferred market-based instrument for mitigating global climate change, with many countries or jurisdictions implementing or planning to implement ETSs[3]. Within the ETSs, offsets will likely continue to play an important role in reducing mitigation costs and promoting low-carbon technologies in the developing world. The Australian Emission Trading Scheme will be introduced in July 2015, which allows the use of CERs and will be linked to the EU ETS. China, the world's largest emitter of GHG, has committed to reduce carbon intensity[4] by 40-45% in 2020 compared with 2005. Part of the reduction will likely be achieved through a market-based system, such as cap-and-trade. The Chinese government has proposed piloting cap-and-trade systems in selected economic sectors and regions before introducing a nationwide ETS. The pilot ETS in Guangdong province now includes carbon credits through carbon sink afforestation projects, indicating the potential role for offsets.

This paper examines how investors' perceptions about the regulatory and administrative framework governing the supply of CERs affects the price of sCERs and the EUA-sCERs price spread. We draw upon IDEACarbon weekly survey data (2008-2010) concerning premiums that investors placed on assuming various levels of project

[3] Jurisdictions that have ETS implementation in place include the European Union; New South Wales, Australia; Alberta, Canada; Tokyo, Japan: New Zealand; Norway; Switzerland; California, the United States; Regional Greenhouse Gas initiative in several eastern states of the United States: United Kingdom Carbon Reduction Commitment Scheme; and Western Climate Initiative in the western states of the United States and some provinces of western Canada. Countries with plans to introduce a national ETS include Brazil, China and the Republic of Korea.

[4] Carbon intensity is the amount of GHG emitted per unit of GDP.

delivery risks in the primary CER market, where project developers negotiate over-the-counter forward agreements to sell CERs before they are issued.

Many factors influence the success of a CDM project and the CER price in the primary market; some are macro-level risks common to all CDM projects, others are project and country specific. Factors related to the political and administrative processes that govern the issuance of CERs are common to all CDM projects, such as registration and verification risks. The premiums that investors put on these risks can be used as proxies for their perception about the stringency of the regulatory and administrative processes leading up to the issuance of CERs. The higher the risk premium the higher the perceived stringency of the regulatory and administrative processes - resulting in longer wait times and/or higher rates of rejection. Regression analysis of the survey and price data shows that premiums placed on registration, verification, and issuance risks are positively correlated with the price levels of sCER, and negatively correlated with the EUA-CER price spread.

To our knowledge, this paper provides the first empirical analysis of the supply factors of CERs as determinants of the sCER price and the EUA-sCER spread. It is also the first study pointing to a connection between the EUA-sCER price spread and investors' perceived project delivery risks in the primary CER market. Building on the analysis by Mansanet-Bataller et al (2010) in examining the price determinants of EUAs and CERs, our paper contributes to the emerging literature on the analysis of the sCER price dynamics and the EUA/CER price spread. The next section of the paper, Section 2, provides a broad overview of international carbon trading, while the following subsections outline the particulars of price formation in the primary and secondary markets for CDM project-based credits. Section 3 outlines the data and econometric specifications for the paper while Sections 4 and 5 present the detailed results of our empirical study. The paper concludes with policy implications and recommendations.

2 An Overview of International Carbon Markets

2.1 EUA and sCER Spot Price Dynamics

CDM projects generate CER credits through a variety of emissions reduction methodologies. Each unit of CERs represents 1 ton of CO_2 emissions (or GHG equivalent) and are traded in EU ETS together with EUAs. At present, the national CER import quotas are fixed at rates varying from 3% to 50% of total emissions, while the aggregate limit or overall “import cap” on the use of project credits in the EU ETS stands at roughly 13.5% of total compliance requirements (Gregoriou and Healy, 2009). The EU ETS is divided into three phases including 2005-2007, 2008-2012 and 2013-2020. Intra-phase borrowing and banking of allowances is permitted under the European framework, while inter-phase borrowing and banking is forbidden between Phases I and II, to contain the fallout from poor policymaking during Phase I. Inter-phase borrowing and banking is allowed between Phases II and III with some restrictions for CERs[5].

Carbon permits are commonly treated in the literature as a pseudo-commodity and their prices as a function of demand and supply (Chesney and Taschini 2009). Taking the EU ETS as an example, supply side factors include allocation of EUAs under

[5] Use of CERs in EU ETS is restricted to the least advanced countries for projects registered after 2012. In addition, credits generated through HFC-23 and N2O projects are prohibited from 1 January 2013.

the national allocation plans, rules on banking and borrowing, the number of CERs issued by the CDM executive board and the import cap imposed by the EU. Demand side factors are determined directly by projected and actual pollution emissions, which are driven by macroeconomic factors such as pollution abatement technologies, weather conditions, economic growth and energy-commodities prices (Alberola, et al 2008). Uhrig-Homburg and Wagner (2006) conducted a survey of carbon market participants that assessed their beliefs surrounding the factors influencing EUA prices. The results indicate that respondents believe regulatory uncertainties and fuel prices have the most significant influence on EUA price formation, followed by political risks, weather variables, technological development, and technical risks. In their 2008 paper, Alberola et al. found that EUA spot prices react to production levels in regulated sectors, natural gas and coal prices, electricity prices, the clean-spark spread, the clean-dark spread, and unexpected temperature changes during cold events.[6] In addition, Mansanet-Bataller and Pardo (2009) adapted an event studies methodology to show that carbon market news significantly influences EUA prices.

The literature is still emerging on factors influencing the price of CERs and the price spread between EUAs and CERs. In their 2010 study, Mansanet-Bataller et al. provide the first empirical analysis of sCER price levels and EUA/sCER price spread dynamics. Specifically, they find that EUA and sCER movements share many of the same determinants, including oil, coal, and gas prices, news events surrounding the linking

[6] The clean-spark spread is the net revenue a natural gas plant makes from selling power after securing the required emissions allowances. The clean-dark spread is a corresponding measure for coal-fired power plants.

mechanism, as well as a momentum indicator that tracks sCER prices lagged five days. For the dynamics of the EUA-sCER spread, they identify as significant determinants a number of market microstructure variables, including proxies of EUA and CER trading activity.

2.2 CDM Projects and the Primary CER Market

Unlike the EUAs allocated directly to installations under the National Allocation Plans of the EU member countries, behind every sCER there is a unique provenance with an implicit background story. CER credits are generated by projects located in non-Annex 1 developing countries, financed and owned by a wide variety of entities, and using alternative methodologies to achieve varying magnitudes and forms of emission reductions across different time frames. All projects undergo a formal review and approval process in order to be credited for their emission reductions. CER purchasing agreements are negotiated between buyer and seller at various stages of the project review/approval process. These purchasing agreements are non-standard – each associated with an individual set of terms that distribute risk between buyer and seller, which are highly relevant to their price. Though the agreements are generally non-standard, it is possible to categorize the most typical deal types (Nordseth, et al 2007). Figure 1 presents the main stages of a CDM project activity cycle and the price spreads reflecting difference in risk distributions between buy and seller. Of course, all differentiation between CER contracts vanishes at the moment they begin trading in the secondary market, as they are then free of risk and all equal in credit to one ton of CO_2

or GHG equivalent. Nonetheless, this section demonstrates how valuable information can be extracted from the dynamics of the primary CER market.

[Figure 1]

All CDM projects formally enter the activity cycle by submitting a Project Design Document (PDD) to a Designated Operational Entity (DOE).[7] This document outlines the methodology that will be used to reduce emissions in addition to a baseline calculation of emissions that would occur in the absence of the project activity. Once the project activity is registered and operational, actual emissions are compared to the baseline in order to determine the number of CERs that should be credited to the project.

Following the project design stage is a validation phase where an independent DOE evaluates the PDD to ensure that the project meets CDM requirements. If the DOE approves the PDD, the project is validated and the DOE submits a request for registration to the CDM Executive Board. Within 8 weeks, the Executive Board will either request a review of the project activity (at which point the project will be delayed at the registration stage), or it will register the project if no issues are found. Registration is the formal acceptance by the Executive Board of the validated project as a CDM project activity. (UNFCCC, 1997)

Once the project is registered, an implementation phase begins in which emissions reductions are monitored and quantified according to the methodology and the baseline set forth in the PDD. Periodically, another DOE (separate from the validating DOE) takes steps to verify the monitored emissions reductions. Certification is

[7] The DOE is an independent consultant that serves as a mediator between the project developer and the CDM Executive Board during several stages of the review process.

the DOE's written assurance to the CDM Executive Board that during a specified time period, a project activity actually achieved the emissions reductions as verified. Issuance of sCERs takes place pending the results of a final completeness check following the submission of a certification request to the CDM Executive Board. (UNFCCC, 1997)

Up to the point of credit issuance, project developers form expectations about the anticipated generation of CERs and their associated revenue streams. Thus, they can (and do) enter into over-the-counter forward agreements that transfer the rights to ownership of future CER streams from project developers (the short parties in the contract) to other carbon market participants (the long parties in the contract). These forward contracts are referred to as primary CERs, while the opaque market in which they trade is aptly termed the primary CER market. According to Cooper and Ambrosi in the World Bank's *State and Trends of the Carbon Market in 2009*, project activities in China accounted for 62% of the total primary CER market as of 2007.

Contrary to sCERs, primary CER forward contracts often embed a degree of uncertainty and default risk, which varies at different stages of the project activity cycle. Settlement of contracts is not guaranteed, and projects can fail any number of review criteria set forth by the CDM Executive Board. This makes forward agreements useful tools for project developers looking to hedge future credit generation and secondary price risks by trading an uncertain and risky stream of future payments for certain (but heavily discounted) compensation in advance of CER issuance.

It is likely that an examination of primary CER prices will reveal key insights about the formation of carbon market expectations and risks. In a 2010 analysis of risk premia in CO_2 allowance markets, Chevallier (2010) notes how expectations and risk preferences of carbon market participants determine futures prices on CO_2 allowances. In particular, he describes how a market participant looking to buy a futures contract will form an expectation about the future spot price of the underlying contract and add a risk premium that compensates him for bearing the risk of unfavorable movements in the spot price. This "expectations approach" is preferable in the carbon markets in the absence of statistical evidence for a cost-of-carry relationship that would justify a theory of storage approach to futures pricing (Chevallier, 2010). In the context of this theoretical framework, we propose a stylized model for pricing a primary CER forward agreement:

$$CER_t = e^{-r(T-t)} \cdot \mathbb{E}[sCER_T \,|\Omega_t] \cdot \mathbb{P}[Project\ Success\,|\Omega_t] \;+\; \pi_t$$

Here, CER_t denotes the primary CER price at time t, T-t is the wait-time-to-issuance, r is the discount rate, and π_t is the risk premium at time t. Both the expectation of the time-T sCER price and the probability of project success are conditional upon the information available to the buyer at time t. In particular, this time-t conditioning information set Ω_t encodes data about the project's current stage of development. As a project moves further along the project activity cycle, the wait-time-to-issuance should decline while the probability of project success should increase, *ceteris paribus*. This is because, as a project nears the issuance stage, it must pass fewer review hurdles (where the CDM Executive Board can potentially delay a project, or even reject it).

While sCERs are free of the kind of risks that are typically associated with primary market CERs, prices of sCERS are affected by the same factors that influence project success and wait-time-to-issuance. The regulatory framework that causes changes in wait-time-to-issuance and project success also changes future supply of sCERs, causing the prices of EUAs and sCERs to change as well. As a result, movements in primary CER price spreads elucidate vital information about expected sCERs supply in the future and should have an impact on sCER prices. As Figures 2 and 3 illustrate, the wait-time-to-issuance is a dynamic feature of the primary CER market that has fluctuated wildly even before the start of the 2008-2012 Kyoto Protocol implementation period. Therefore, it is clear that primary-market spread dynamics belong in a model aiming to trace the evolution of the sCER prices and the EUA-sCER spread.

Figure 2 illustrates the average wait time until registration after a CDM project passes validation and submits a request for registration to the CDM Executive Board. This figure shows how from the beginning of the 2008 through May 2008, the average wait time between validation and registration increased by about 100 days, while the period since May 2008 has seen a remarkable decline in the average wait time from 250 days in May 2008 to 50 days in November 2009. Similarly, Figure 3 captures the average wait time until sCER issuance as emissions reductions undergo a completeness check after verification and certification.

[Figure 2]

[Figure 3]

In the context of the broader emissions trading market, Hitzemann and Uhrig-Homburg (2010) examine the price dynamics of emission permits in a long-term equilibrium model under uncertainty. They take into account consecutive trading periods and assume firms under regulation operate for multiple trading periods. The regulator allocates a certain amount of permits to each regulated firm and the permits are bankable. A penalty is imposed on companies that have realized more emissions at the end of a specific trading period than they can cover with allowances. A firm finds an optimal way of hedging the risk of paying penalties by choosing an appropriate trading strategy. The equilibrium spot price of a permit includes two value components: firms (i) saving a penalty payment which is weighted by the probability that penalties arise, and (ii) receiving an additional payment equal to present value of leftover permits at the end of the last trading period.

In the case of sCERs, if a regulatory framework experiences a change that slows down the process that CERs are issued, it will cause less sCERs to be issued by the end of the trading period. The effect of tighter future supply of emission credits is equivalent to reduction of future permits available to cover emissions. This leads to higher current spot permit prices including both sCERs and EUAs, and vice versa. In addition, the change in the regulatory framework also will also affect the price spread between EUAs and sCERs, which is in part due to the EU ETS import cap of 13.4%. Lowering future supply of sCERs reduces the probability of sCER supply exceeding the import cap set by the EU and improves the fungibility of sCERs. This will lead to narrowing of the EUA-sCER price spread, and vice versa.

The relationships between a change of the regulatory framework and sCER prices and the EUA-sCER spread will be tested in the following section using IDEAcarbon survey data and European Climate Exchange trading data. The econometric specifications based on the above theoretical arguments are also presented in the next section.

3. Data

3. 1 CER Primary Market Survey Data

The variables for primary CER forward price spreads are constructed using the results of the weekly IDEACarbon pCER Index™. Altogether, there are a total of 115 weekly observations spanning two years of the EU ETS Phase II from March 27, 2008 through August 26, 2010. This survey asks respondents how much they would be willing to pay for primary-market CERs bearing:

A) Validation, registration, verification,[8] and issuance risks (CER_{At});

B) Registration, verification, and issuance risks only (CER_{Bt});

C) Verification and issuance risks only (CER_{Ct}); and finally

D) Issuance risks only (CER_{Dt}).

According to Point Carbon's database of actual transactions, there has been a clear tendency towards an increased price differentiation between categories, indicating an increased understanding of the risk premiums associated with these transaction categories (Nordseth, et al, 2007). This dataset offers a rare glimpse into the opaque

[8] The IDEACarbon pCER Index™ asks respondents how much they would be willing to pay for validation, registration, volume, and issuance risks in the primary CER market. As the risk of project over/underperformance enters into the picture at the verification stage of the CDM project activity cycle, this paper chooses to identify the volume risk with verification risk.

world of primary CER pricing, where contracts are negotiated over-the-counter between project developers and other carbon market participants. Although broad categorizations of the most typical deal types can be identified based on the risk distribution between buyer and seller, actual contracts in the primary CER market are typically non-standardized and prices vary within each category according to a particular project's underlying performance risk and a set of terms and conditions associated with the transaction (Nordseth, et al, 2007).

The IDEACarbon survey abstracts from project-specific or country-specific risk factors and can be interpreted as the average price that respondents are willing to pay (per CER) for primary CER forward contracts from average projects at different stages of the project activity cycle. The survey respondents' willingness to pay for bearing various types of risks are determined by their perceptions about the opportunity cost of capital related to probability of project success, wait-time-to-issuance and expected future sCER prices. The stringency of the CDM Executive Board's review standards and their efficiency in processing the applications would have a direct impact on the wait-time-to-issuance and the probability of project success. In addition, the CDM Executive Board affects future sCER prices through a general equilibrium effect. Therefore, the survey respondents' willingness to pay acts as a proxy for the stringency and efficiency of the regulatory framework with regards to the various stages of the review process. We construct the primary-market CER forward contract price spreads as follows:

Issuance Spread: $Issuance_t = sCER_t - CER_{D t}$

Verification Spread: $Verification_t = CER_{D t} - CER_{C t}$

Registration Spread: $Registration_t = CER_{C t} - CER_{B t}$

Validation Spread: $Validation_t = CER_{Bt} - CER_{At}$

3.2 EUA and sCER Prices and Their Determinants

The spot sCER price ($sCER_t$) is obtained from the published Reuters sCER Price Index. Since sCER are forward contracts, the EUA prices are the rolled-over nearest-maturity EUA futures contract (EUA_t) listed on the European Climate Exchange (ECX) over the same period. For both sCER and EUA prices, weekly averages are calculated based on daily prices for the same period as when Ideacarbon conducted weekly surveys of the primary CER market. The EUA-sCER price spread (hereafter $Spread_t$) is constructed through subtracting the spot sCER price ($sCER_t$) from the rolled-over nearest-maturity EUA futures contract over the same period.

EUA and sCER prices fluctuate widely and are influenced by macro and micro level determinants in the short and long-run. A number of macro drivers affect the supply and demand for permits, including overall GHG quota allocation in Kyoto Annex B countries, voluntary GHG mitigation, and the supply of CDM and other projects that generate carbon credits. In the short-run, EUA and sCER price drivers include institutional events causing supply and demand shocks, fuel prices (notably the coal-gas price differential), European weather and factors affecting speculative activities.

For energy prices, we use average weekly Brent (BRENT) and natural gas futures prices (GASPOOL), coal CIF ARA[9] (ARA_COAL) and the baseload electricity price in Germany (GER_BASELOAD). Also used are indicators of market trends, including the market volatility index (VIX_CLOSE) and the change in the yield spread between short

[9] CIF ARA defines the price of coal inclusive of freight and insurance delivered to the large North West European ports.

and long bonds (ΔYIELD_SPREAD). To capture arbitrage opportunities to take advantage of the EUA-sCER price spread, we also use EUA trading volume and CER trading volume as potential liquidity proxies (since different liquidity risk profiles might contribute to the price spread between the EUA and the CER). Intuitively, these contracts should be more liquid on higher trading days than on lower trading days.

In terms of EUA allocation issues, intra-phase supply of EUAs is fixed by the National Allocation Plans (NAP), although announcements on the relative strictness of the NAPs have a strong impact on EUA prices (Alberola et al. 2008, Mansanet-Bataller and Pardo 2009). Furthermore, EUA prices are influenced by the future role of EUAs during Phase III (2013-2020). Therefore major news events releasing new information about NAPs and the future role of EUAs are also EUA and sCER price drivers.

One important news event related to sCERs is the linking of the Kyoto Protocol's International Log (ITL) and the EU ETS's Community Independent Transaction Log (CITL) on October 16th, 2008. Only after the linking of the two logs could CERs purchased by private buyers can be included in the buyer's national registry account under the ITL. Therefore, we include *ITL* in our specification as an indicator variable, separating the periods before and after the ITL-CITL link.

Table 1 summarizes the data on the sCER and EUA prices and their driving factors included in the analysis, while Figure 4 illustrates the dynamic evolution of the EUA-sCER price spread and the Issuance, Verification, Registration, and Validation primary CER price spreads. Following a brief period of widening spreads, May 2008 marked a turning point after which primary- and secondary-market prices and spreads declined through the following winter. These trends match up with observations on timelag dynamics in Figures 2 and 3 of Section 2.3. In general, the price spread between the sCER and EUA is both larger and more volatile during 2008 than subsequently in 2009 and 2010. This raises questions about the stability of the carbon market and possibility of structural breaks in the data, which will be examined in the empirical analysis.

[Table 1]

[Figure 4]

4. Cointegration Analysis

Although EUAs and sCERs are not the same asset, they share many common price drivers. In fact, EUAs are often times used as a bench mark for negotiating prices of CERs in the primary market. Therefore, it is likely that there exist long-term equilibrium relationships between the two variables. When there are deviations from the long-term equilibrium relationship, economic forces act quickly to eliminate the deviations through arbitrage opportunities. Following the methodology of Mansanet-Bataller et al. (2010), we first identify the possible cointegration relationship between EUAs and sCERs, and then employ a vector autoregressive (VAR) model to model the data-generating process for each variable. To validate the approach, we conducted a Cointegration ADF test (CADF) and the results support using cointegration techniques to model the long-run relations (Table 2).

[Table 2]

Next we fitted a VAR model relating first differences in sCER prices ($\Delta sCER_t$) and that of EUA prices (ΔEUA_t) in order to model the data-generating process for each variable (Table 3). Within the VAR framework, a likelihood ratio test confirms the optimality of a 6-period lag selection. Based on the above modeling results, we isolate the innovations in $\Delta sCER_t$ not explained by ΔEUA_t and its own lagged values. Hereafter dEUAt refers to the residuals of ΔEUA_t in the VAR(6) model relating ΔEUA_t and $\Delta sCER_t$, and similarly dCERt refers to the residuals of $\Delta sCER_t$ in the VAR(6) model. As expected, $\Delta sCER_t$ and ΔEUA_t are confirmed to be stationary processes.

[Table 3]

5. Empirical Model Specification and Estimation Results

Following Mansanet et al (2010), we employed the GARCH to examine the price drivers of sCERs and the EUA-sCER price spread[10]. First, we use the residuals of the VAR(6) model for sCER ($dsCER_t$) as dependent variables and the residuals for EUA, and the first differences of primary CER price spreads of a set of supply and demand factors as independent variables to analyze the price drivers of sCERs. Second, we use the first differences of the EUA-sCER price spread as the dependent variable and the same set of independent variables as above. The empirical model specification for the VAR(6) sCER residuals is the following:

[10] Mansanet et al (2011) also employs a modified model (TGARCH). In a TGARCH model, the conditional standard deviation is a piecewise linear function of past values of the white noise. This specific functional form allows the volatility to react differently depending on the sign of the lagged error term. In our estimation, the sign of the lagged error did not make a difference. So we do not follow Mansanet et al (2011) in using the TGARCH approach, but limited our estimation to the GARCH.

$dsCER_t = \delta_0 + \delta_1 \, dEUA_t + \delta_2 \, \Delta Validation_t + \delta_3 \, \Delta Registration_t + \delta_4 \, \Delta Validation_t + \delta_5$

$\Delta Issuance_t + \delta_i \, \Delta$other supply and demand factors $+ \varepsilon_t$

$\Delta Spread_t = \gamma_0 + \gamma_1 \, dEUA_t + \gamma_2 \, \Delta Validation_t + \gamma_3 \, \Delta Registration_t + \gamma_4 \, \Delta Validation_t +$

$\gamma_5 \, Issuance_t + \gamma_i \, \Delta$other supply and demand factors $+ \varepsilon_t$

We include variables relevant to energy prices and financial market trends. For energy prices, we include average weekly Brent (BRENT) and natural gas futures prices (GASPOOL), coal CIF ARA[11] (ARA_COAL) and the baseload electricity price in Germany (GER_BASELOAD). Also included is the market volatility index (VIX_CLOSE), and ΔYIELD_SPREAD the change in the yield spread between short and long bonds. Dummy variables are also included, indicating major events relevant to the supply and demand of EUA and CERs.

The estimation results for the change in the VAR(6) residuals, dsCER, using a GARCH are shown in Table 4. The results reveal a strong relationship between the change in the residuals for sCER and EUA. This testifies to the common sources of innovation between the two series. They also indicate a strong relationship with the change in the registration price spread from the survey and the issuance spread. Interestingly, none of the other price and financial market variables capturing supply and demand influences are significant. It is possible that the EUA residual has already captured the supply and demand influences.

[Table 4]

[11] CIF ARA defines the price of coal inclusive of freight and insurance delivered to the large North West European ports.

A simpler ordinary least squares equation is also estimated for the change in the spread, ΔSpread and presented as Table 5. This equation reveals a strong relationship with the change in the price of European Union Allocations -- ΔEUA. It also shows a strong link with the change in the registration, verification, and issuance price premiums. ΔVIX_CLOSE, the change in the market volatility index, is also significant at 10% level. This indicates that the EUA-sCER spread is at least partially affected by factors related to arbitrage opportunities.

[Table 5]

Figure 4 above raises some troubling questions about the stability of the carbon market. The price spread between the sCER and EUA is both larger and more volatile during 2008 than subsequently in 2009 and 2010. To examine this apparent structural shift, we carried out a Chow test for coefficient stability for the basis specification in Table 5. This test shown in Table 6 confirmed our suspicions that the relationship is not stable. It indicates that the hypothesis that there is no breakpoint at the end of 2008 can be rejected at least at the 5 per cent level of significance using an F test and at a higher level of significance using the log likelihood ratio or the Wald Statistic.

[Table 6]

This structural shift is likely caused by the 2008 financial crisis, reflecting the rapid deterioration of the economic situation and massive reduction of industry's demand for allowances. The EUA price experienced dramatic decline from around €30 in June 2008 to less than €6 in February 2009, with the price of CER closely tracking that of EUA.

The estimation results for the equation in the two parts of the sample are shown in Tables 7 and 8. Each part passes a Chow test for stability if its sample is again divided in two. These results show a strong relationship between the change in the spread and the change in the price of the EUA and for two or three of the four changes in primary CER spread variables. These support our hypothesis that regulatory stringency in issuing CERs has significant price effects in the secondary market and the support is particularly strong at the issuance stage.

[Table 7]

[Table 8]

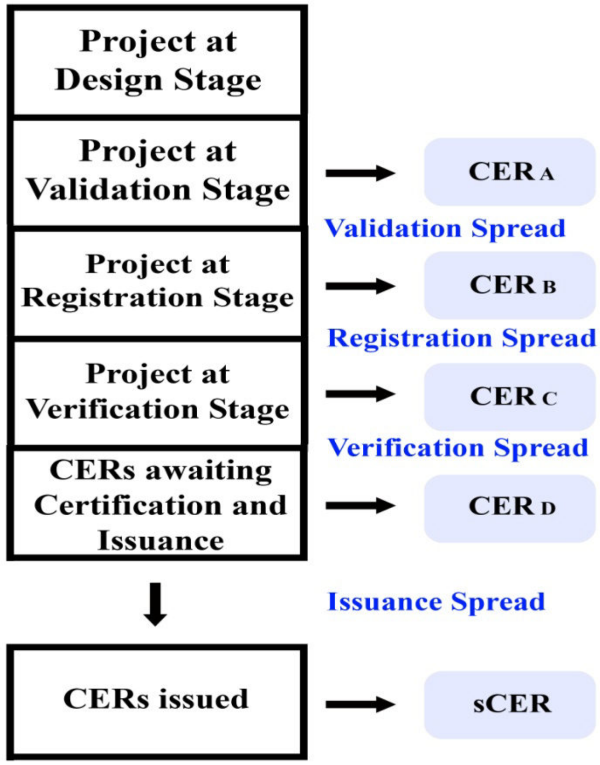
6. Conclusions

This paper provides the first empirical analysis of how the regulatory stringency and efficiency of the CDM framework affect CER prices in the secondary market and the price spread between EUAs and CERs. We used survey data on investors' demand for risk premium at four stages of forward contracting in the primary CER market to proxy for the regulatory stringency and efficiency of the CDM framework. Cointergration analysis and GARCH modeling were conducted to analyze the sCER and EUA prices, the EUA-sCER spread and their driving factors.

We show that there is a strong relationship between the change in the residuals for sCER and EUA prices, indicating the common sources of innovation between the two series. This confirms that they share many common price drivers. The proxies for regulatory stringency and efficiency have significant and sizable impact on the CER price in the secondary market and the EUA-sCER price spread. In addition, the carbon market was not stable during 2008-2010, with a structural shift at the end of 2008, likely due to the 2007-2008 financial crisis.

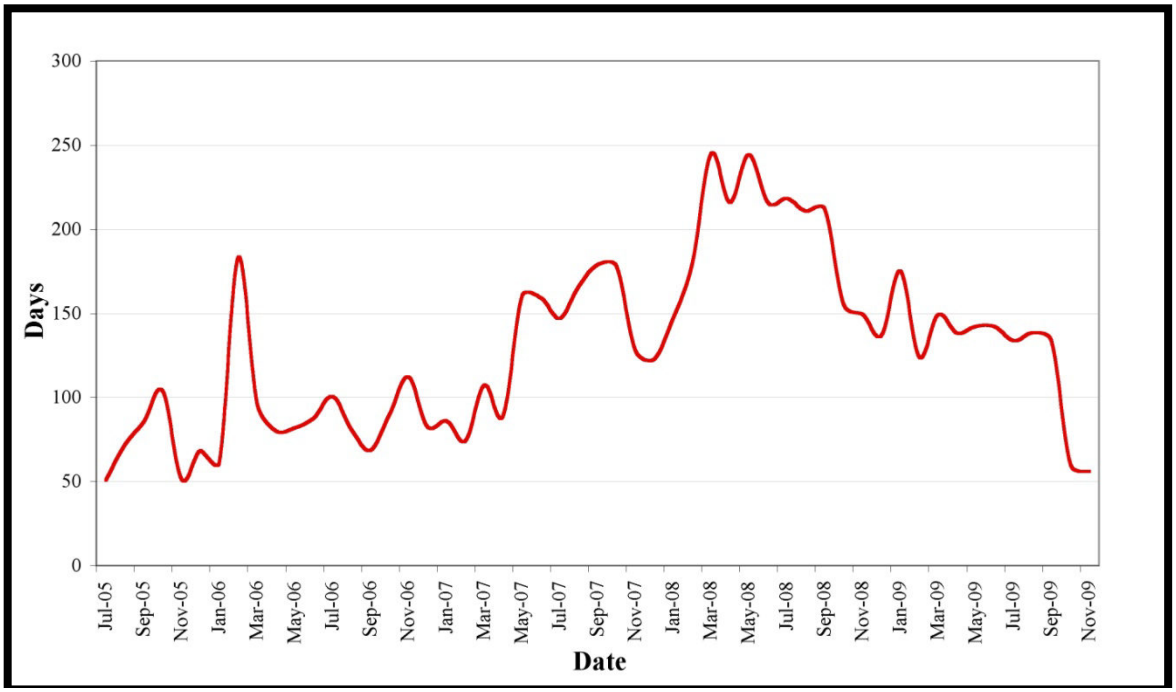
While economic efficiency is an advantage offered by offsets, the regulatory framework and processes have an impact on the cost of supplying carbon credits. Careful consideration is needed in the design and implementation of the regulatory framework and processes to realize the full potential of economic efficiency offered by offset mechanisms. Given that change in economic conditions can cause paradigm shifts in the emissions market, timely adjustments of the relevant supply and demand factors are important for maintaining market stability.

Figure 1: CDM Project Activity Cycle



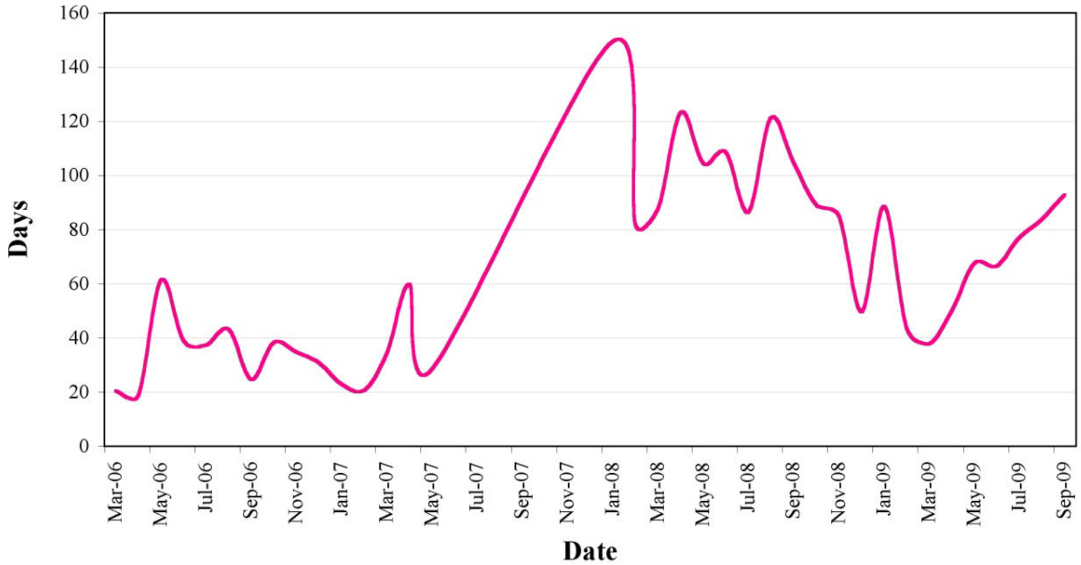
Note: Adapted from the UNFCCC's "Guide to do a CDM project activity."

Figure 2: Average Timelag Between Validation and Registration



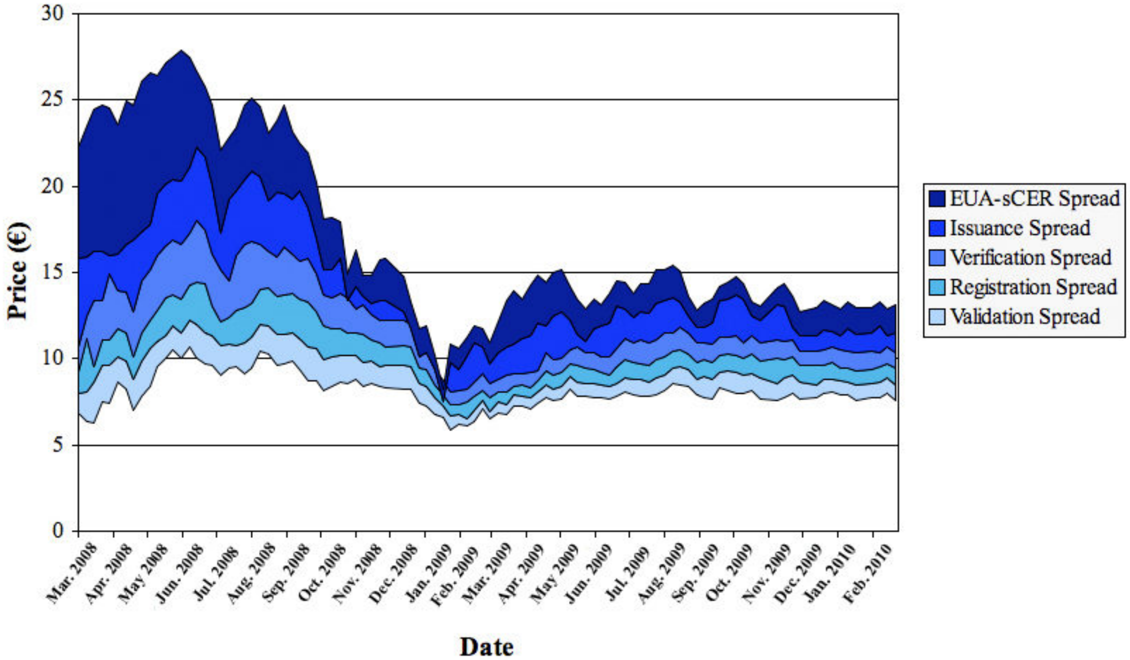
Note: Adapted from the CDM Pipeline Overview published by CD4CDM

Figure 3: Average Timelag Between Registration and Issuance



Note: Adapted from the CDM Pipeline Overview published by CD4CDM

Figure 4: Carbon Market Price Spreads



Note: Primary-market spreads are derived from the results of the weekly IDEACarbon pCER Index™.

Table 1: Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Price Series				
EUA_t	16.56	4.84	8.20	27.88
$sCER_t$	13.89	3.18	7.55	22.15
$CERA_t$	8.10	0.92	5.85	10.64
$CERB_t$	9.23	1.19	6.55	12.23
$CERC_t$	10.40	1.64	7.36	14.39
$CERD_t$	11.88	2.36	8.11	18.00
Price Spreads				
$Spread_t$	2.66	2.06	0.6	8.69
$Validation_t$	1.12	0.43	0.41	2.33
$Registration_t$	1.17	0.53	0.47	3.05
$Verification_t$	1.48	0.83	0.57	3.88
$Issuance_t$	1.94	1.13	-1.24	5.08
First Differences				
$\Delta Spread_t$	0.0363	0.48	-1.18	1.73
$\Delta Validation_t$	-0.0026	0.18	-0.69	0.62
$\Delta Registration_t$	-0.0035	0.33	-2.18	1.82
$\Delta Verification_t$	-0.0055	0.41	-1.58	2.51
$\Delta Issuance_t$	-0.0190	0.73	-2.25	2.90
Technical Indicators				
ΔEUA Open $Interest_t$	2.636	16.74	-131.00	18.12
ΔEUA $Volume_t$	0.000032	5.97	-19.74	21.68
VAR(6) Residuals				
$\Delta sCER_t$	7.40E-18	0.684	-2.267	2.203
ΔEUA_t	-6.48E-18	0.792	-2.873	2.368

Note: There are 127 weekly observations on each variable in this summary (7 of the observations were missing and had to be interpolated between neighboring observations), with first differences representing week-on-week changes. EUA_t is the price of the rolled-over nearest-maturity EUA Futures Contract on the ECX, $sCER_t$ is the price of the Reuters sCER Price Index, and $CERA_t$ through $CERD_t$ are the survey results from IDEACarbon's pCER Index™ on the willingness to pay for primary CER forward contracts with different risk profiles. $Spread_t = sCER_t - EUA_t$, $Validation_t = CERB_t - CERA_t$, $Registration_t = CERC_t - CERB_t$, $Verification_t = CERD_t - CERC_t$, $Issuance_t = sCER_t - CERD_t$. ΔEUA Open $Interest_t$ is the first difference of the open interest of EUA Futures Contracts (in millions) on the ECX, and ΔEUA $Volume_t$ is the first difference of total EUA trading volume for EUA Futures Contracts (in millions) on the ECX. ΔCER_t and ΔEUA_t are the residuals of the first-differenced EUA price series in the VAR(6) Model relating first-differenced EUA and CER prices.

Table 2: Cointegration Analysis for sCER and EUA

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	2	2	1	2
Max-Eig	1	2	2	1	2

Information Criteria by Rank and Model

Log Likelihood by Rank (rows) and Model (columns)					
0	-208.933	-208.933	-207.629	-207.629	-204.341
1	-197.412	-197.407	-197.084	-196.921	-195.604
2	-196.584	-192.491	-192.491	-192.267	-192.267

Akaike Information Criteria by Rank (rows) and Model (columns)					
0	3.687418	3.687418	3.698839	3.698839	3.677719
1	3.564128*	3.580436	3.591533	3.605262	3.600067
2	3.616125	3.581811	3.581811	3.610928	3.610928

Schwarz Criteria by Rank (rows) and Model (columns)					
0	4.055158	4.055158	4.112547	4.112547	4.137395
1	4.023803*	4.063095	4.097176	4.133889	4.151677
2	4.167736	4.179389	4.179389	4.254474	4.254474

Lags interval: 1 to 4

*Critical values based on MacKinnon-Haug-Michelis (1999)

Table 3: Vector Autoregression Estimates VAR(6) for ΔsCER and ΔEUA

	ΔsCER	ΔEUA
ΔsCER(-1)	-0.282462	-0.344998
ΔsCER(-2)	-0.070878	0.148117
ΔsCER(-3)	-0.37396**	-0.400856**
ΔsCER(-4)	-0.018711	-0.112126
ΔsCER(-5)	0.341939**	0.082711
ΔsCER(-6)	0.06657	0.195124
ΔEUA(-1)	0.351721**	0.358315**
ΔEUA(-2)	0.160011	-0.022965
ΔEUA(-3)	0.388944**	0.403456**
ΔEUA(-4)	-0.085105	0.014765
ΔEUA(-5)	-0.414389**	-0.208154
ΔEUA(-6)	0.093257	0.02165
Constant	0.003887	-0.047132
R-squared	0.209857	0.13829
Adj. R-squared	0.121243	0.04165
Sum sq. resids	55.62892	74.57058
S.E. equation	0.721038	0.834818
F-statistic	2.368216	1.430975
Log likelihood	-124.1453	-141.7279
Akaike AIC	2.285755	2.578798
Schwarz SC	2.587733	2.880776
Mean dependent	-0.02625	-0.080083
S.D. dependent	0.769173	0.852766
Determinant resid covariance (dof adj.)		0.104267
Determinant resid covariance		0.082899
Log likelihood		-191.1377
Akaike information criterion		3.618961
Schwarz criterion		4.222918

Sample (adjusted): 5/15/2008 8/26/2010 n= 120

** significant at 1% level.

Table 4: Vector Autoregression Estimates VAR(6) for dsCER and ΔEUA

Dependent Variable: dsCER
Method: ML - ARCH (Marquardt) - Normal distribution
Sample (adjusted): 5/15/2008 8/26/2010 n= 120
Convergence achieved after 33 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(12) + C(13)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
dEUA	0.48853	0.049622	9.845122	0
Constant	0.004218	0.026109	0.161564	0.8716
ΔValidation	0.008131	0.132765	0.061242	0.9512
ΔRegistration	0.543301	0.131496	4.13168	0
ΔVerification	0.193861	0.117109	1.655386	0.0978
ΔIssuance	0.410813	0.055898	7.349322	0
ΔGER_BASELOAD	0.001787	0.022195	0.080514	0.9358
ΔGASPOOL	0.040061	0.030135	1.329393	0.1837
ΔARA_COAL	-0.008047	0.007576	-1.062211	0.2881
ΔVIX_CLOSE	0.003265	0.004804	0.679618	0.4967
ΔYIELD_SPREAD	-0.168476	0.255796	-0.658632	0.5101
	Variance Equation			
C	0.137834	0.017377	7.931865	0
GARCH(-1)	-0.97223	0.025203	-38.57662	0
R-squared	0.836447	Mean dependent var		7.40E-18
Adjusted R-squared	0.821443	S.D. dependent var		0.683718
S.E. of regression	0.288912	Akaike info criterion		0.402394
Sum squared resid	9.098257	Schwarz criterion		0.704372
Log likelihood	-11.14361	Hannan-Quinn criter.		0.525028
Durbin-Watson stat	1.863639			

Note: ΔGER_BASELOAD is the change in the baseload electricity price in Germany, ΔGASPOOL is the change in the price of gas, ΔARA_COAL the change in the price of coal, ΔVIX_CLOSE the change in the market volatility index, and ΔYIELD_SPREAD the change in the yield spread between short and long bonds.

Table 5: Regression Results for ΔSpread for 2008 to 2010

Dependent Variable: ΔSpread
Method: Least Squares
Sample (adjusted): 4/03/2008 8/26/2010
Included observations: 126 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔEUA	-0.624361	0.055697	-11.20989	0
Constant	-0.0226	0.026749	-0.844878	0.3999
ΔValidation	0.066479	0.180169	0.368983	0.7128
ΔRegistration	-0.520617	0.097527	-5.338191	0
ΔVerification	-0.46524	0.090567	-5.136968	0
ΔIssuance	-0.60653	0.058318	-10.40045	0
ΔGER_BASELOAD	-0.017283	0.028043	-0.616288	0.5389
ΔGASPOOL	-0.024402	0.038898	-0.627338	0.5317
ΔARA_COAL	0.007953	0.007986	0.995922	0.3214
ΔVIX_CLOSE	-0.01023	0.005638	-1.814371	0.0722
ΔYIELD_SPREAD	0.404765	0.281899	1.435852	0.1538

R-squared	0.648622	Mean dependent var	-0.03627
Adjusted R-squared	0.618067	S.D. dependent var	0.482178
S.E. of regression	0.29799	Akaike info criterion	0.499737
Sum squared resid	10.21175	Schwarz criterion	0.747349
Log likelihood	-20.48344	Hannan-Quinn criter.	0.600334
F-statistic	21.22826	Durbin-Watson stat	1.971999
Prob(F-statistic)	0		

Table 6: Chow Stability Test for ΔSpread Equation during 2008-2010

Chow Breakpoint Test: 12/25/2008
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 4/03/2008 8/26/2010

F-statistic	1.905386	Prob. F(11,104)	0.0467
Log likelihood ratio	23.13319	Prob. Chi-Square(11)	0.0169
Wald Statistic	20.95925	Prob. Chi-Square(11)	0.0338

Table 7: Regression Results for ΔSpread for 2008

Dependent Variable: ΔSpread
Method: Least Squares
Sample (adjusted): 4/03/2008 12/25/2008
Included observations: 39 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔEUA	-0.65366	0.105753	-6.180984	0
Constant	0.086019	0.068841	1.249527	0.2218
ΔValidation	-0.463001	0.332104	-1.394144	0.1742
ΔRegistration	0.62459	0.156442	3.992475	0.0004
ΔVerification	0.59857	0.152162	3.933765	0.0005
ΔIssuance	0.68848	0.104226	6.605618	0
ΔGER_BASELOAD	0.0218	0.056556	0.385451	0.7028
ΔGASPOOL	0.068255	0.081083	0.841791	0.407
ΔARA_COAL	-0.014357	0.014189	-1.011821	0.3203
ΔVIX_CLOSE	0.021625	0.01231	1.756784	0.0899
ΔYIELD_SPREAD	-1.144511	0.739719	-1.547223	0.133

R-squared	0.77395	Mean dependent var	0.102564
Adjusted R-squared	0.693218	S.D. dependent var	0.743416
S.E. of regression	0.411763	Akaike info criterion	1.296006
Sum squared resid	4.747356	Schwarz criterion	1.765215
Log likelihood	-14.27211	Hannan-Quinn criter.	1.464354
F-statistic	9.586634	Durbin-Watson stat	2.104174
Prob(F-statistic)	0.000001		

Table 8: Regression Results for ΔSpread for 2009 to 2010

Dependent Variable: ΔSpread
Method: Least Squares
Sample: 1/01/2009 8/26/2010
Included observations: 87

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔEUA	-0.564247	0.071585	-7.882188	0
Constant	0.003603	0.023764	0.151628	0.8799
ΔValidation	0.558679	0.236828	2.359009	0.0209
ΔRegistration	0.305681	0.194347	1.572859	0.1199
ΔVerification	0.20746	0.193308	1.073206	0.2866
ΔIssuance	0.466389	0.076014	6.135526	0
ΔGER_BASELOAD	0.028162	0.032319	0.871378	0.3863
ΔGASPOOL	-0.007446	0.044693	-0.16661	0.8681
ΔARA_COAL	-0.00777	0.013421	-0.578912	0.5644
ΔVIX_CLOSE	0.001958	0.006279	0.311872	0.756
ΔYIELD_SPREAD	0.052363	0.261149	0.200511	0.8416
R-squared	0.77395	Mean dependent var		0.006552
Adjusted R-squared	0.693218	S.D. dependent var		0.3014
S.E. of regression	0.411763	Akaike info criterion		-0.084067
Sum squared resid	4.747356	Schwarz criterion		0.227714
Log likelihood	-14.27211	Hannan-Quinn criter.		0.041477
F-statistic	9.586634	Durbin-Watson stat		2.144202
Prob(F-statistic)	0.000001			

References

Alberola, É., Chevallier, J., 2009. "European Carbon Prices and Banking Restrictions: Evidence from Phase I (2005-2007)." *The Energy Journal* 30, 51-80.

Alberola, É., Chevallier, J., Chèze, B., 2008. "Price drivers and structural breaks in European carbon prices 2005-2007." *Energy Policy* 36, 787-797.

Chesney, M., Taschini, L., 2009. "The Endogenous Price Dynamics of Emission Allowances and an Application to CO_2 Option Pricing." *Swiss Finance Institute Research Paper Series Number 08-02*.

Chevallier, J., 2010. "Modeling risk premia in CO2 allowances spot and futures prices." *Economic Modeling*, forthcoming.

Chevallier, J., Ielpo, F., Mercier, L., 2008. "Risk Aversion and Institutional Information Disclosure on the European Carbon Market: a Case-Study of the 2006 Compliance Event." *Energy Policy* 37, 15-28.

Flåm, K., 2009, "Restricting the import of 'emission credits' in the EU: a power struggle between states and institutions." *International Environmental Agreements: Politics, Law and Economics* 9, 23-38.

Gregoriou, A., Healy, J., 2009. "Trading Costs for Futures in the European Union Emissiosn Trading Scheme." Available at: http://ssrn.com/abstract=1411610

Hitzemann, S. and Uhrig-Homburg M., Understanding the Price Dynamics Emission Permits: A Model for Multiple Trading Periods, 2010

IPCC (2007). "Glossary J-P. In (book section): Annex I. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (B. Metz et al. Eds.)". Cambridge University Press, Cambridge, U.K., and New York, N.Y., U.S.A.

Mansanet-Bataller, M., Chevallier, J., Hervé-Mignucci, M., Alberola, É., 2010. "The EUA-sCER Spread: Compliance Strategies and Arbitrage in the European Carbon Market." *Mission Climat Working Paper Number 2010-6.*

Mansanet-Bataller, M., Pardo, A., 2009. "Impacts of regulatory announcements on CO_2 prices." *The Journal of Energy Markets* 2, 75-107.

Nordseth, M., Buen, J., and Lokshall, E., 2007. CER Market Dynamics, in Equal Exchange: Determining a Fair Price for Carbon, CD4CDM

Uhrig-Homburg, M., Wagner, M., 2006. "Success Chances and Optimal Design of Derivatives on CO_2 Emission Certificates." *Working Paper, University of Karlsruhe.*

United Nations Framework Convention on Climate Change (UNFCCC), 1997-2010. "Kyoto Protocol" and "Guide to do a CDM Project Activity" Available at: http://unfccc.int/2860.php

World Bank, 2010. "World Development Report 2010: Development and Climate Change". Washington DC.