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Role of carbon swap trading and energy prices in price correlations and volatilities between carbon markets☆

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ABSTRACT

The present paper theoretically and empirically examines the role of carbon swap trading and energy prices in volatilities and price correlations between the EU and Kyoto Protocol emissions trading schemes. A supply and demand based correlation model between EUA and sCER price returns is proposed in detail using inverse Box–Cox type marginal abatement cost (MAC) curves and simple emission reduction volume processes. The model includes financial players' EUA–sCER swap transaction in boom periods of carbon prices using the logit model for EUA and EUA–sCER swap volume correlations, and stronger energy price impacts on EUA prices than sCER prices using a mean-reverting lognormal process for energy prices. The empirical studies using EUA and sCER prices estimate the model parameters, resulting in a positive EUA volume impact on EUA–sCER swap transactions and a positive energy price impact on EUA prices. It is shown that high EUA–sCER price correlations during high EUA price periods stemmed from EUA–sCER swap transactions, whereas high EUA–sCER price correlations during the period of financial turmoil with low EUA prices came from the drop in energy prices. We also show that the leverage effects often observed in security markets exist in both the EUA and sCER markets according to the price–volatility relation.

1. Introduction

It is well known that carbon markets try to link with other carbon markets in order to provide the world's carbon market participants flexibility in the use of carbon assets. A typical example is the EU emission trading scheme (EU ETS). It allows the EU ETS participants to import certified emission reductions (CERs) generated from the clean development mechanism (CDM) projects under the Kyoto protocol as an alternative to EU allowances (EUAs), which are allocated and exchanged in the EU ETS. Focusing on this market linkage between EUAs and secondary CERs (sCERs), market players may exploit arbitrage opportunities between the EUA and sCER markets, referred to as EUA–sCER swap, as an alternative investment. As the arbitrage trading volume increases, the political linkage between the two carbon markets will affect the correlation structure of carbon prices. In reality, it is observed in EUA and sCER futures markets that their prices seem to move together, and this is empirical evidence of the carbon markets' linkage. It is also known that energy prices affect carbon prices to some extent, while the level of the influence depends on the carbon market structure made of energy related and unrelated emission reduction technologies. The emission reduction technologies often relevant to energy in carbon markets determine the shapes of the marginal abatement cost curves, affecting energy–carbon price synchronizations and changes. Energy prices will also be a key driver of the carbon price correlation and volatility structure. Theoretically and empirically, this paper tries to find more detailed evidence and the reasons for the volatility structure and price linkage between carbon markets, taking into account the impacts of carbon swap trading and energy prices on carbon markets.

In the last decade, the development of carbon markets has attracted great academic interest. Fehr and Hinz (2006) propose an equilibrium price model for EUA prices taking into account fuel switching between natural gas and coal fired power plants. Benz and Trück (2009) employ an AR-GARCH Markov switching price return model to capture regime changes between different phases of the EU ETS and heteroskedasticity. Daskalakis et al. (2009) compare existing popular diffusion and jump diffusion models, with the results in favor of the Geometric Brownian motion with jumps to fit historical EUA spot prices, unlike the mean-reverting processes often used for commodity price modeling. Seifert

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et al. (2008) propose a stochastic model of CO_2 prices which do not have any seasonal pattern, as often observed in commodity markets. Paolella and Taschini (2008) also propose mixed normal and mixed stable GARCH models to capture the heavy tails and volatility clustering in the U.S. SO_2 permits and EUA price returns, which are not modeled using any mean-reversion and seasonality. Uhrig-Homburg and Wagner (2009) examine the relation between carbon spot and futures prices traded on the Powernext and the European Climate Exchange. Trück et al. (2015) conduct empirical analyses of EUA convenience yields using the spot and futures prices traded on the EEX and presenting a convenience yield model based on the spot prices and volatilities. Kanamura (2009b) also investigate the characteristics of carbon asset prices, resulting in the possibility of classifying carbon assets into non commodity assets. Gorenflo (2013) analyzes the pricing and lead–lag relation between EUA spot and futures prices.

Other papers focus on price determination in carbon markets. The relations between EUA futures prices and macroeconomic factors, including stock and bond market variables, are found in Chevallier (2009). Fezzi and Bunn (2009) show that carbon prices accompanied by natural gas prices drive electricity prices in the UK. Hintermann (2010) investigates whether marginal abatement costs explain EUA prices in the first phase of the EU ETS or not. Bredin and Muckley (2011) examine the impacts of economic growth, energy prices, and weather conditions on EUA futures prices. Chevallier (2011a) suggests that yearly compliance events and growing uncertainties in post-Kyoto international agreements may explain the instability in carbon price volatilities. Chevallier (2011b) develops a carbon pricing model considering two fundamental EUA price drivers of economic activity and energy prices. Gronwald et al. (2011) find a strong dependence between EUA futures price returns and those of other financial assets and commodities during the period of the financial crisis. Aatola et al. (2013) discover a strong relation between EUA prices and energy prices, including German electricity prices and gas and coal prices.

While these empirical studies focus on carbon price models and the empirical analyses of a single carbon market, they do not seem to pay attention to the characteristics of the price correlations between carbon markets. Grüell and Taschini (2012) assess the linkage between emission trading schemes by focusing on price convergence, but unfortunately they do not use any carbon price model. Mansanet-Bataller et al. (2011) show that EUA–sCER price spreads are mainly driven by EUA prices and market microstructural variables. Koop and Tole (2013) models the relation between EUA and CER using an existing econometric model, resulting in contemporaneous causality between three variables: the prices of CER, and EUA spot and futures. Nazifi (2013) identifies factors impacting on the dynamics of the price spread between EUAs and CERs by detecting changes in the structural relation between them. These results are insightful but the linkage between two carbon markets may not have been investigated so far using a supply–demand based carbon price model. Since sCERs are allowed for the offset to meet their emission reduction target inside the EU ETS, these two carbon markets may have a strong relation with each other regarding their prices. In addition, the correlation and volatility structures of carbon prices are strongly affected by the market marginal abatement cost curve, made of various energy price related and unrelated emission reduction technologies. But these carbon market characteristics do not seem to have been employed so far to examine carbon price correlations and volatilities. This paper theoretically and empirically investigates the volatility structure and dynamic linkage between EUA and sCER prices taking into account emission reduction technologies and the linkages between the carbon markets: EUA–sCER swap trading and energy price impacts.

We propose a detailed model of the correlation between EUA and sCER price returns using the supply–demand relation between two carbon markets, i.e., inverse Box–Cox type marginal abatement cost curves and simple emission reduction volume processes, which is based on Kanamura (2015). The model includes financial players' EUA–sCER swap transactions in boom periods of carbon prices using a logit model for EUA and EUA–sCER swap volume correlations, and the stronger impacts of energy prices on EUA prices than on sCER prices using a mean-reverting lognormal process for energy prices. Empirical studies using EUA and sCER prices estimate the model parameters, resulting in a positive impact of the EUA volume on the EUA–sCER swap transactions and a positive impact of energy prices on EUA prices. It is shown that the high EUA–sCER price correlations during periods of high EUA prices stemmed from the increase in EUA–sCER swap transactions, whereas high EUA–sCER price correlations during the period of financial turmoil with low EUA prices came from the decrease in energy prices. Then we show that the leverage effects often observed in security markets exist in both the EUA and sCER markets, according to the price–volatility relation, which may suggest flatter MAC curves for the carbon markets than the exponential function.

This paper is organized as follows. Section 2 proposes a detailed correlation model of price returns between EUA and sCER products. Section 3 presents the results of empirical studies using the spot and futures prices both in the EUA and sCER markets. Section 4 concludes.

2. The model

Carbon prices are determined using the supply–demand relation based on the marginal abatement cost and emission reduction volume in carbon markets according to carbon market observations. In addition, a certain amount of emission credits or allowances in one carbon market are allowed to be used as an alternative in the other carbon market, resulting in a volumetric linkage between the carbon markets stemming from swap transactions in carbon products. Furthermore, it is observed that energy prices affect carbon prices via the MAC curve, which, in particular, is highlighted in EUA markets. It is well known that EUA and sCER are more frequently traded than the other carbon markets and are considered as the two leading carbon assets. We try to model EUA–sCER price correlations and volatilities using a detailed supply–demand relation, which includes the volumetric linkage owing to EUA–sCER swap transactions and the differences between the carbon markets in terms of energy price impacts based on the general framework of Kanamura (2015).

For a cap and trade system such as the EU ETS, the market participants who are obliged to reduce their emissions possess an upward sloping marginal abatement cost (MAC) curve. These emission reductions are represented by the differences between the emissions and the capped allowances for companies. The equilibrium prices for EUAs are obtained from the intersection between the MAC curve and the emission reduction volume. For baseline and credit type assets such as sCERs, the pricing mechanism is the same as the EU ETS. Emission credits are generated along with the upward sloping MAC curve for sCER in the order of the low cost emission reduction technologies until the credit volume meets the emission reduction volume needed for the emission reduction obligation of the covered entities. Then, the equilibrium price is determined by the intersection between the MAC curve and emission reduction volume.

The demand elements of carbon markets are modeled using the emission reduction volumes needed in each of the whole EUA and sCER markets. It is assumed that the emission reduction amounts fluctuate stochastically due to variations in CO_2 or GHG emissions, which have the mean-reverting property. We write V_t and D_t for the emission reduction volumes of EUA and sCER, respectively[1]

$$dV_t = \mu_V\left(1-\frac{\lambda}{\mu_V}V_t\right)dt + \sigma_V dv_t, \tag{1}$$

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[1] We basically suppose that V_t and D_t are positive. But the emission reduction volume is calculated as emissions minus the emission reduction target. Thus it allows for a negative emission reduction volume in the overallocation of EUAs.