Price discovery and volatility spillovers in the European Union emissions trading scheme: A high-frequency analysis

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ABSTRACT

This paper models the relationship of European Union Allowance spot- and futures-prices within the second commitment period of the European Union emissions trading scheme. Based on high-frequency data, we analyze the transmission of information in first and second conditional moments. To reveal long-run price discovery, we compute common factor weights of Schwarz and Szakmary (1994) and information shares of Hasbrouck (1995) based on estimated coefficients of a VECM. To analyze the short-run dynamics, we perform Granger-causality tests. We identify the futures market to be the leader of the long-run price discovery process, whereas the informational role of the futures market increases over time. In addition, we employ a version of the UECCC-GARCH model as introduced by Conrad and Karanasos (2010) to analyze the volatility transmission structure. The volatility analysis indicates a close relationship between the volatility dynamics of both markets, whereas in particular we observe spillovers from the futures to the spot market. As a whole the investigation reveals that the futures market incorporates information first and then transfers the information to the spot market.

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1. Introduction

Since the implementation of the European Union emissions trading scheme (EU-ETS) in January 2005, trading activity within the futures markets for European Union Allowances (EUAs) has steadily expanded over the first two commitment periods. However, as a consequence of the overallocation with allowances in Phase I, spot market trading activity broke down and prices converged to zero within this period. With the start of Phase II, spot market trading activity strongly rose and was even higher compared to the period prior to the spot market collapse.

The main objective of this study is to analyze the price discovery process in the most liquid EUA spot and futures markets in Phase II of the EU-ETS. In addition, we investigate the joint volatility dynamics in both markets. Consequently, the paper directly attempts to assess the structure of information transmission in the EU-ETS. Contrary to previous studies such as Uhrig-Homburg and Wagner (2009), Milunovich and Joyeux (2010), and Chevallier (2010), we make use of daily as well as intraday data at the frequencies of 10 and 30 min. We conduct the investigation of the price transmission between both markets on the basis of vector error correction models. Besides the analysis of common factor

measures as suggested by Schwarz and Szakmary (1994), Gonzalo and Granger (1995) and Hasbrouck (1995) to reveal the long-run price discovery process, we also investigate the short-run causality structure by means of Granger-causality tests. In order to assess the transmission of information in the second conditional moment, we estimate a dynamic version of the unrestricted extended CCC-GARCH model as developed by Conrad and Karanasos (2010), whereas each market's conditional volatility is determined by lagged volatilities and lagged shocks of both markets. This model is flexible enough to capture negative volatility spillovers, leverage effects and dynamic conditional correlations.

The first result is the absence of a cointegration relationship in daily spot and futures prices. Hence, at this frequency we cannot identify any market to be the price leading market. This result is in line with the findings of Milunovich and Joyeux (2010) and Chevallier (2010). However, extending the data from daily to intraday frequency, the analysis reveals a completely different picture. Based on high-frequency data, the results strongly support the existence of a cointegration relationship, and hence underpin the close link between both markets. Moreover, we show that drawing meaningful economic inference on each market's contribution to the price discovery process requires to conduct the analysis on the basis of data at the highest frequency of 10 min. The reason for this is an increasing correlation between the innovations of the two markets at lower frequencies which induces an identification problem. Most

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importantly, we find that the futures market incorporates information first and then transfers it to the spot market. While at the early stage of Phase II the futures market attracts 70% of the price discovery process, this portion even increases over time. Consequently, our results considerably extend the findings of Uhrig-Homburg and Wagner (2009) and Chevallier (2010) as they show the close relationship between both markets and the futures market's informational role.

Second, concerning the short-run causality structure, we find univariate Granger-causality from the futures to the spot market in daily data. However, the investigation of high-frequency data reveals a bidirectional causality structure between both markets. This result is robust with respect to the choice of the intraday frequency.

Third, in the volatility analysis we observe a similar pattern as in the price discovery analysis. In the early stage of Phase II we find unidirectional spillovers from the futures market volatility and from shocks in the futures market to the spot market's volatility. There is no such impact into the opposite direction. Contrary, in the more mature stage only lagged spot market shocks but not lagged spot market volatility affect futures market volatility. In addition, the impact of lagged futures market volatility on current spot market volatility considerably increases over time. Consequently, the results of the volatility analysis confirm the existence of the close link between both markets, which we also find in the price discovery analysis. Further, these results contradict the findings of Milunovich and Joyeux (2010) who observe a weak link between both markets' uncertainties in Phase I making use of daily data. Finally, the investigation of the DCC-structure indicates that the dynamic conditional correlation between spot and futures returns increases from about 0.1 at the start of Phase II to approximately 0.6 at the end of the sample period. In summary, we find strong evidence for a close relationship between the price and volatility dynamics in both markets that even intensifies over time. Further, making use of high-frequency data, we identify the futures market to be the price leading market. This result is consistent with previous findings for mature financial markets, as Tse (1999) among others reports.

We organize the remainder of the paper as follows. In Section 2, we give an overview on the related literature while Section 3 summarizes the key elements of the EU-ETS. Section 4 describes the data and gives an overview on the relationship between commodity spot and futures prices in general. Section 5 outlines the methodology we use in the empirical analysis, while Section 6 summarizes the estimation results and provides an interpretation of the empirical findings. Finally, Section 7 concludes.

2. Related literature

With improved data availability since the introduction of the EU-ETS, a fast growing number of empirical studies related to this market has been conducted. Besides the analysis of the impact of market fundamentals and regulatory aspects on the allowance price dynamics (see Mansanet-Bataller et al. (2007), Alberola et al. (2008) or Mansanet-Bataller and Pardo (2009) among others) and the relationship between macroeconomic performance and allowance prices (see Chevallier (2009) or Conrad et al. (2011, forthcoming) among others), the investigation of statistical price properties is in the focus of this field of research. While Paolella and Taschini (2008), Daskalakis et al. (2009) or Chevallier and Sevi (2011) and Rittler (2011) investigate individual volatility dynamics in the futures markets, other studies explicitly assess the relationship of the joint dynamics of spot and futures prices.

Uhrig-Homburg and Wagner (2009) investigate the joint development of spot and futures EUA prices in Phase I in the framework of a cost-of-carry relationship. The authors argue that for companies under the EU-ETS there is no benefit of holding EUAs in terms of meeting unexpected demand to keep the production process going since these companies need EUAs only once a year to fulfill regulatory requirements. In their empirical analysis, Uhrig-Homburg and Wagner (2009) find a cointegration relationship between observed futures prices and theoretical futures prices which they derive in the cost-of-carry model. They find that the futures contract leads the long-run price discovery process. Contrary, Milunovich and Joyeux (2010) find inconsistent evidence for the existence of such a relationship, and doubt the validity of the cost-of-carry relation. More recently, making use of vector error correction models and controlling for structural breaks, Chevallier (2010) confirms the results of Milunovich and Joyeux (2010) for Phase II.

As a whole, previous studies assessing the relationship between spot and futures prices yield mixed evidence. Yet, apart from Chevallier (2010) all studies refer to Phase I, and moreover, Uhrig-Homburg and Wagner (2009), Milunovich and Joyeux (2010), and Chevallier (2010) conduct their analysis on the basis of daily data, which the authors justify by the low spot market liquidity in Phase I. However, Hasbrouck (1995) and Tse (1999) among others show that the usage of intraday data leads to more informative results compared to daily data. For the EU-ETS, Benz and Hengelbrock (2008) provide a first high-frequency price discovery analysis for Phase I. They study the joint price dynamics of futures contracts traded at the ECX and at NordPool, respectively. The authors find strong evidence for the existence of a cointegration relationship and the price leadership of the futures contract traded at the ECX. However, they critically mention the low trading activity at NordPool.

Concerning the transmission of information in the second conditional moment, that is the analysis of volatility spillovers, empirical evidence is rare. Only Milunovich and Joyeux (2010) address this topic in the framework of the GARCH-BEKK model. The authors conclude that there seems to be minor relevance of informational spillovers in the volatility of spot and futures prices. However, the study again refers to Phase I and is based on daily data.

3. The European Union emissions trading scheme

In January 2005 the EU-ETS formally entered into operation. Within the framework of the Kyoto Protocol the European Union has established the EU-ETS with the ultimative objective to reduce greenhouse gas emissions in a cost efficient way. To fulfill their commitments, the European Community and its Member States agreed to construct an efficient European market for European Union Allowances. One EUA warrants the right to emit one tonne of CO_2-equivalent, whereas next to carbon dioxide the EU-ETS also covers further anthropogenic greenhouse gases that are supposed to have an impact onto climate change.[1] The EU-ETS is organized in several commitment periods. The first period lasted from 2005 to 2007 and served as a pilot period, the second one lasting from 2008 to 2012 coincides with the first Kyoto commitment period. The third period covers the years 2013–2020.

The market is a cap and trade market, whereas all participating installations, companies operating in the sectors production and processing of steel and iron, minerals, energy, or pulp and paper, receive a certain volume of EUAs to meet their compliance requirements, according to the emissions caps the European Commission determines and fixes in National Allocation Plans (NAPs).[2] The

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[1] Besides carbon dioxide, the EU-ETS accounts for methane, nitrous oxide, hydro fluorocarbons, perfluorocarbons and sulphur hexafluoride.

[2] The European Commission plans to also cover the aviation sector's emissions by the EU-ETS from 2012 on.