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A study on the volatility spillovers, long memory effects and interactions between carbon and energy markets: The impacts of extreme weather

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ABSTRACT

Due to the connections of energy uses, carbon emissions and climate, this study investigates the interactions, volatility spillovers, and long memory effects for carbon, oil, natural gas and coal markets by using FIEC-HYGARCH model. It also discusses the mediating effect of extreme weather. The empirical results verify that the FIEC-HYGARCH model can capture the long-term volatility behavior. The futures returns of carbon and energy have long memory and own-mean spillover effects. Moreover, the conditional variances also have volatility spillovers, long memory effects and amplitudes. Hence, there exist dynamic interrelationships among the futures returns of carbon and energy. Further, it also extends the long memory and causes various spillover effects by incorporating extreme weather into the model, indicating that extreme weather has certain impacts on carbon, oil, natural gas and coal markets.

1. Introduction

The problem of CO_2 emissions from fossil fuel uses (oil, natural gas, and coal), has caused a great deal of concerns around the world. In order to control carbon dioxide emissions, the carbon market has developed since 2005 based on the mechanisms of the Kyoto Protocol. The carbon price is affected by carbon emissions, which implies that energy prices have certain impacts on it. Moreover, information shocks may lead to any fluctuations in these markets, thus the information transmission and spillover effect cannot be ignored. In general, the prices are not reflected immediately by news or a shock, which implies that past long-lagged prices may still have strong influences on today's prices (i.e. long memory). Furthermore, abnormal weather leads to more energy uses and higher CO_2 emissions, which may reflect on carbon and energy prices. Therefore, this study tries to investigate the interactions, volatility spillovers, and long memory effects between carbon and energy markets by using FIEC-HYGARCH model, and the impacts of extreme weather are also taken into consideration.

Human beings have consumed a large amount of fossil fuels and altered the use of land to improve their economic activities since the Industrial Revolution. Moreover, other human activities, such as deforestation and burning waste, have changed the lifestyle of individuals and the environment. These human activities have caused a serious problem, greenhouse effect, which brings various impacts on the environment, such as climate change. Although these changes have made humans become richer, the environment has also been harmed severely due to the greenhouse effect.

The greenhouse effect is due to the increase of greenhouse gases (GHGs) in the atmosphere, especially during the period of booming economy with higher energy uses. And the increase of greenhouse gases is believed to be the result of the preceding description about human activities. It actually has caused a severe problem, global warming. Global warming has been causing many problems, such as ice melting, rising sea levels and even climate changes. All of these phenomena are harmful to the ecosystem environment and threaten the lives of human beings. According to IPCC Fourth Assessment Report (2007), global anthropogenic GHG emissions have increased by about 70% between 1970 and 2004. Anthropogenic GHG emissions include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6). Carbon dioxide is the most important anthropogenic GHGs due to its largest share of GHGs and significant annual growing emissions. The rising of CO_2 concentration is mainly contributed by fossil fuel use, and it is the main cause of greenhouse effect and global warming. Hence, this study investigates the relationships of carbon and energy markets.

Other than the above description, it is necessary to understand the formation of carbon market. In recent decades, there has been more and more concern about the issue of climate change and global warming. The United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) mutually established the Intergovernmental Panel on Climate Change (IPCC). Furthermore, the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty for member countries to reduce global warming and stabilize the concentration of GHGs.

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On 11 December 1997, the Kyoto Protocol was adopted by Conference of the Parties (COP-3) of UNFCCC, and entered into force on 16 February 2005. It requires 37 industrialized nations and the European community to reduce GHG emissions and meet their targets by these three market-based mechanisms. These mechanisms are Emissions Trading (ET), Clean Development Mechanism (CDM) and Joint Implementation (JI), which are offered for nations to meet their individual targets, and they encourage green investment and achieve the cost-effectiveness of emission targets. In Article 17 of the Kyoto Protocol, Annex B Parties (parties with commitments under the Kyoto Protocol) have to fulfill their obligations to meet individual emissions targets. The carbon market was created under the Kyoto Protocol in 2004, and it allows countries and businesses to trade emission units, or "assigned amount units" (AAUs). Through the carbon market, countries that have extra emission units can sell them to the countries that demand for them; those countries that lack emission units can buy them from other countries. Hence carbon becomes a new commodity and it is traded like other commodities. Carbon emissions trading has become a means for countries to reduce the amount of carbon emissions to meet their obligations and thereby mitigate global warming.

In terms of global carbon market, the EU Emission Trading Scheme (EU ETS), the world's largest carbon market, was launched in 2005. The global carbon market has attracted numerous investors' attention, and the volume of emissions trading has been growing steadily in recent years. This is the main reason why we discuss the example for the relationships between carbon and energy markets in European countries.

Based on the previous description, there are several motivations for this study. First of all, most literatures have showed the determinants of carbon prices, such as energy prices, weather variations, economic growth, and policy issues (Christiansen et al., 2005; Springer, 2003). Some of them even focus more on the interactions between carbon and energy markets for the Phase I (2005–2007). Carbon price is affected by energy prices significantly due to the connection of fossil fuel uses and carbon emissions. Therefore, understanding the connection of carbon and energy markets provides the basic background knowledge for constructing the empirical model.

Except to the understanding of carbon and energy markets, the market volatilities are needed to be considered. Information shocks may lead to fluctuations in one market, or even transmit its volatility to other markets. Thus the information transmission and spillover effect are needed to be considered. Furthermore, the price performance today could be affected by past long-term news or a shock (i.e. long memory). Hence, the spillover and long memory effects are one of the major concerns in this study.

While most studies use regression methods or GARCH models to capture the interactions of carbon and energy markets, we hardly found the literatures that focus on the spillover and long memory effects (i.e. the current performance is affected by the past long-term behavior, and leads to a long range dependence in the time series). Therefore, we use FIEC-HYGARCH (fraction integrated error correction-hyperbolic GARCH) to analyze the interactions, spillovers and long memory effects between carbon and energy markets.

Except the energy prices, weather variations are another important carbon price driver. Numerous studies have showed the effect of climate on energy and carbon prices. Both temperature increases and decreases can lead to more energy consumption and increase their CO_2 emissions, hence raise the carbon prices. Therefore, we need to consider the impact of weather variables on carbon market by using extreme temperatures as dummy variables in the empirical model.

This study contributes to a better understanding of the interactions of carbon and energy markets in Europe. We also try to capture the spillovers and long memory effects between these two markets whether with weather variable or not. The empirical results of this study can provide better investing information for the global and domestic investors, including asset allocation, portfolio diversification and hedging strategy. For industrial firms, this study can help them to do better decisions or hedging strategy towards the impacts under environmental policies. Besides, this study can also provide the related information of global carbon market for Taiwanese government or agencies to establish domestic carbon market in the future.

The remaining parts of this study are organized as follows. Section 2 outlines the literature review. Section 3 summarizes the empirical methodology, followed by the empirical results reported in Section 4. Finally, Section 5 presents some concluding remarks.

2. Literature review

2.1. The interactions of carbon and energy markets

There is a great deal of literatures that captures the interactions of carbon and energy markets. Reinaud (2007) shows the links between CO_2 prices and electricity prices. It shows that low electricity prices lead to higher electricity consumption and higher CO_2 emissions; allowances demand may rise as a result and push CO_2 prices increased. Besides, a relatively high gas price causes more use of coal, which increase the demand of CO_2 allowances, therefore increase the permit price. Mansanet-Bataller et al. (2007) show how energy sources, being one of the main factors in determining carbon prices, affect carbon price level of 2005. The coefficient for lagged Brent oil and lagged natural gas price changes is positive, which means CO_2 price changes increase with Brent and gas price changes. However, coal price changes and the quotient between the gas price changes do not influence carbon price changes significantly. To detect the relations between carbon and energy markets, Bunn and Fezzi (2007) use SVAR (Structural Co-integrated VAR model) to analyze the mutual relationship between electricity, gas and carbon prices in the daily spot markets in the U.K. They find that gas price firstly affects EUA price, and both of them affect electricity price together; in the short-term dynamics, carbon prices react significantly and quickly to a shock on gas price. Rickels and Grace (2007) also analyze the relationship between the ETS and energy prices of the years 2005 and 2006. Their results show that the increase of oil and gas prices leads to switching effect towards coal, which increases emissions and the demand of CO_2 allowances, and therefore drives up the CO_2 prices. While the increase of coal price leads to lower emissions, and therefore reduces the demand of allowances and CO_2 prices.

Alberola et al. (2008) use Newey–West OLS to analyze European carbon prices of years 2005 to 2007. The result shows that Brent oil, natural gas, electricity, clean spark and switch prices affect carbon prices positively, while coal and clean dark prices affect carbon prices negatively. To understand the determinants of the EU allowance prices, Hsiao (2008) demonstrates the effects of energy prices on EU allowance prices in the period of 2005 to 2008. The empirical results show that oil, gas and electricity prices affect carbon price positively and significantly, while coal price brings significant negative effect to carbon price. Keppler and Mansanet-Bataller (2010) use Granger causality test to analyze the interaction between the EU ETS and European electricity markets for January 2005 to December 2007. The result shows that the EU ETS has an impact on the European power sector, and carbon prices drive electricity prices, most notably in the spot market. It also indicates that gas prices drive carbon prices and hence electricity prices. Hintermann (2010) tries to find the causality of fuel prices and EUA prices during the first phase of EU ETS. However, in his study in the period 2005–2007, there was a structural break in EUA price determination after April 2006 (emission verification). Therefore, the author divides the data into three categories: the full period, pre-crash period, and post-crash period. The results show that gas prices are positive and significant in determining carbon prices for all periods. And the coal prices bring negative and significant effect on carbon prices. Recently, Tsai (2010) analyzes carbon prices volatility (EUA) of years 2008 to 2009 along with considering energy prices and extreme weather dummy variables. This article has several findings. Firstly, the coal