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The dynamic volatility spillover between European carbon trading market and fossil energy market

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ABSTRACT

With the rapid spread of carbon trading in the world, the interaction of carbon prices and fossil energy prices has raised growing attention, but little research has discussed their time-varying correlation and dynamic volatility spillover. This paper employs the threshold dynamic conditional correlation (DCC) generalized autoregressive conditional heteroscedasticity (GARCH) model and the full Baba, Engle, Kraft and Kroner (BEKK) GARCH model to explore these issues, for the daily data of European carbon futures prices and the three fossil energy prices (coal, natural gas and Brent oil) from January 2 2008 to September 30 2014. The results indicate that, first, there is significant unidirectional volatility spillover from coal market to carbon market and from carbon market to natural gas market, whereas there exists no significant volatility spillover between carbon market and Brent oil market. Second, carbon market and fossil energy markets have significantly positive correlation across time. Specifically, among the three fossil fuels, coal market has the highest correlation with carbon market, followed by natural gas and Brent oil markets. Finally, as for the three fossil fuels, their price decrease may have stronger impact on carbon price volatility than their price increase with the same degree, while there is asymmetric impact of carbon price increase and decrease only on Brent oil price volatility. These results may help investors to well configure their portfolios and manage their investment risks, and help emission trading installations to join in carbon market in a cost-effective way.

1. Introduction

In order to address climate change caused by worldwide greenhouse gas emission, carbon markets have been growing at a rapid rate since the Kyoto Protocol came into force on February 16, 2005, especially the European Union Emissions Trading Scheme (EU ETS). For example, the transaction volume in the EU ETS increased from 94 million tons to 8.7 billion tons during 2005–2013 and reached 86% of global carbon trading volume in 2013 (European Union, 2013; Bloomberg New Energy Finance, 2014). Accordingly, carbon markets play an important role in effectively curbing global carbon emission. As Jackson and Robertson (2009) argue that changing the behavior of government and industry through carbon trading is likely to have more immediate impact on carbon emission than encouraging individuals to buy low-carbon products and services.

Despite an emerging market, the EU ETS has become an important part of global financial markets and commodity markets and also has proved to be an alternative investment channel to make profits and diversify asset risks (Zhang and Wei, 2010b; Subramaniam et al., 2015). However, there are sharp changes in carbon prices in recent years, which are closely correlated with energy prices mainly for three reasons. First and foremost, fossil energy combustion proves the main source of carbon emission, and lower fossil energy price can cause the increase of energy consumption, which may often lead to higher carbon emission demand and higher carbon prices. Second, global increasing population and continual economic growth especially in developing countries have caused the increasing fossil energy consumption, thereby driving up carbon emission and carbon prices. Finally, the various sensitivity of energy use to weather changes in different seasons (Fikru and Gautier, 2015) also should be responsible for the volatilities of carbon and energy prices. For example, Liu and Chen (2013) find

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that extreme weather has certain impact on the changes of carbon and energy prices.

Under this circumstance, it is of great importance to explore the relationship between carbon prices and fossil energy prices, which can be confirmed from the following two aspects. First of all, manufacturing companies are struggling to reduce greenhouse gas emission. Typically, greenhouse gas emission is one of the performances of so-called environmental management system (Chiarini, 2014a, 2014b). Carbon emission reduction and the large fluctuations of carbon prices have significant impact on the operational performance of industrial sectors covered by the emission trading scheme (Gallego-Alvarez et al., 2015). Thus, the industrial sectors require sufficient information between carbon and energy prices to adjust their energy consumption structure moderately and achieve the optimal carbon emission reduction strategies. Second, with the rapid development of advanced communication technologies and global financial markets, the markets of various assets have become more and more closely correlated. Hence, it is important for investors and policy makers to well know the complex correlation between carbon and energy markets. However, we find that up to now, there has been little research investigating the time-varying correlation and dynamic volatility spillover between carbon and energy markets (Marimoutou and Soury, 2015; Sheinbaum et al., 2011; Yu et al., 2015).

Therefore, this paper contributes to the existing literature in two aspects. For one thing, it measures the asymmetric shocks of positive and negative information as well as volatility persistence on carbon and energy markets, and evaluates the dynamic conditional correlation (DCC) between them with the DCC threshold GARCH (DCC-TGARCH) model. For another, it explores the time-varying volatility spillover between carbon and energy markets with the full BEKK-GARCH model (Engle and Kroner, 1995), which covers not only the direction but also the magnitude of volatility spillover.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces the data descriptions and research methods. Section 4 presents the empirical results and discussions. Finally, Section 5 concludes this paper and puts forward some suggestions.

2. Related literature review

In academia, the topic about carbon pricing mechanisms has produced much discussion and a wealth of studies have shown that carbon markets are closely associated with fossil energy markets (Nazifi and Milunovich, 2010; Aatola et al., 2013). Overall, that is mainly due to two reasons.

On the one hand, fossil energy accounts for 80% of global energy consumption (International Energy Agency, 2015a) and its combustion proves the main source of carbon emission in the world. In particular, fossil energy is the primary fuel for power generation enterprises, which leads to the volatilities of fossil energy prices and carbon prices becoming the principal considered factors when European Union power enterprises evaluate their generation costs and make investment decisions. In fact, the interaction between fossil energy prices and carbon prices has been widely concerned in the existing research (Alberola et al., 2008).

First of all, the fluctuation of coal price proves to be a key factor affecting the moving trend of carbon prices. For example, Giorgio (2014) argues that coal price is the chief factor influencing electricity prices, which causes the bidirectional causality between carbon prices and electricity prices. Similarly, Chevallier (2011) discovers that coal prices can affect carbon prices significantly. Hammoudeh et al. (2014b) find that the correlation is negative between American coal prices and European Union carbon prices, and the increasing coal prices can cause the decrease of carbon prices, while the higher taxes of coal consumption can reduce carbon prices effectively. Moreover, Hammoudeh et al. (2015) claim that the decreases in coal prices have a stronger impact on carbon prices in the short-run than the increases.

Second, the volatilities of natural gas prices can influence enterprise carbon emission demand and carbon prices, because natural gas has become an important fuel for power generation in developed countries, such as Europe. For instance, Carlo and Derek (2009) hold that carbon prices can affect electricity prices through natural gas prices and the prices of carbon and electricity are both influenced by natural gas prices. Feng et al. (2011) argue that the gap between natural gas prices and coal prices has begun to shrink since Germany used natural gas for power generation in September 2006, which caused significant impact on the movement of carbon prices. Hammoudeh et al. (2014a) find that the increase of natural gas prices of America can affect European Union carbon prices positively when carbon prices are higher, while the effect will become negative when carbon prices are lower.

It should be noted that the fuel switch between coal and natural gas for power generation can also have influence on carbon prices. For example, Bertrand (2014) finds that the consumption switch degree between coal and natural gas will become deeper in power enterprises when uncontrolled carbon emission increases, and at this moment, natural gas prices may affect carbon prices more significantly. Dowds et al. (2013) find that a shift of fuel consumption from coal toward natural gas is sufficient to carbon emission reduction in power enterprises, and even relatively smaller amount of fuel switch can have significant impact on electricity and carbon prices when they can lead to the changes of marginal generating fuel costs.

Moreover, the changes of oil prices can also affect carbon prices by influencing traffic demand and carbon emission. Oil not only proves an important fuel for partial electricity plants and has conversional relationship with coal and natural gas, but also serves as the primary fuel for transportation. For example, Morrow et al. (2009) state that the transportation alone consumes the majority of imported oil in America and produces a third of total US carbon emission. Furthermore, Zhang and Wei (2010a) investigate the dynamic relationship between European Union carbon prices and fossil energy prices, and find out significant cointegration relationship between the two markets and their time-varying long-term equilibrium relationship. Recently, Hammoudeh et al. (2015) argue that crude oil prices can have long-run negative and asymmetric effect on carbon prices.

On the other hand, both the turbulences of macroeconomic policies and financial markets can affect carbon and energy prices, which may further promote the interaction between them. This is mainly due to the fact that, besides the commodity property, both carbon markets and fossil energy markets have obvious political and financial properties (Fan et al., 2013; Zhang and Huang, 2015). For example, Reboredo (2014) discovers that the changes of oil price are closely associated with macroeconomic and financial variables, and may transmit the financial uncertainties to carbon markets. Yu and Mallory (2014) find that the depreciation (appreciation) of European currencies can cause lower (higher) carbon prices through energy alternative mechanisms; and the shocks on exchange rates can affect carbon markets via energy markets. They also discover that the depreciated euro can lead to the increase of coal prices and the decrease of carbon credit prices.

Besides the close price linkages, many empirical studies show that there exists significant volatility spillover between carbon and energy markets with various types of GARCH models. For example, Byun and Cho (2013) investigate the relationship among carbon

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