Journal of Theoretical and Applied Information Technology
15th December 2012. Vol. 46 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SPILLOVER EFFECTS ON CARBON TRADING PRICE OF INTERNATIONAL OIL PRICE

[1,2]SHUANGYING WANG [2]AIWEN ZHAO

[1] Department of Management, QuFu Normal University, Rizhao 276826, China

[2]College of Management, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

ABSTRACT

Along with the arrival of the low carbon economy, the Clean Development Mechanism project is more important to China. By analyzing spillover effects on Chicago Climate Exchange (CCX) carbon market of oil prices by GARCH, it found that the mean and volatility spillover effects between international oil price (WTI) and CCX carbon trade price were significant. The volatility of CCX carbon trading price was influenced itself, at the same time, it was influenced by the volatility of WTI oil price, and spillover effects from WTI fluctuation were more significant than the effects from CCX price fluctuation. International oil price rises will lead to the future price of carbon of Chicago Climate Exchange increases. The effects of international oil price fluctuations to the carbon market were positive, conversely the effects were non-significant.

Keywords: *International Oil Price, Carbon Trade Price, GARCH Model, Spillover Effect*

1. INTRODUCTION

With the constant study of climate change, green house gas emissions and the associated policies won more and more concern among governments and interest groups. The era of cheap energy was replaced by the era of low-carbon economy. Behind the low-carbon economy is the huge economic gains and losses, also changes of international status. It needs joint efforts to combat climate change, but it is also a stage for new economic game among different countries [1].

As one of the most effective means to allocate resources, carbon trading market price signal can guide enterprises to improve the energy structure, energy efficiency and reduce carbon emissions [2]. Carbon trading prices are formed in carbon emission trading according to the carbon emissions trading quotas and their commitments to cutting carbon emissions. Since the entry into force of the Kyoto Protocol, the international carbon market has been developed a lot and plays a significant role in promoting the transition to a low carbon development model in various countries. There are two international carbon trading systems. One is the total control and quota trading system represented by European emissions trading system. This system is strictly restrained by sound international and domestic legal system, which is the main international carbon trading market. EU emissions trading system (EU ETS) fulfills the function of reducing greenhouse gas emissions. The other is represented by the Chicago Climate Exchange, a voluntary emissions trading system, which is because facing the end. As the result of different carbon emissions obligations and participated in different trading contracts, it has not a unified, continuous carbon trading price. China's current carbon trading system is a voluntary trading system. As different carbon trading prices forming different market signals, the resource allocation efficiency is low. Study on the price discovery function in carbon trading market has the important meaning in the resources allocation.

Oil is one of the most important financial and energy products. And oil price volatility is likely to affect the development status and situation of the international carbon trading market. The oil price was the important elements to influence the world economy [3]. And the oil price could produce spillover effects to many international macroeconomic factors [4, 5]. International oil prices are the impact factor to many kinds' futures markets, and it displays the price discovery function to several major financial markets. It had two-way spillover effects between WTI and the New York gasoline prices spot price, at the same time WTI had remarkable one-way price discovery function to Singapore gasoline price [6]. The oil price had two-way spillover effects between WTI and China oil spot market. Based on the former research, the international oil price had significant price discovery function to many market [7, 8]. As the important international financial products under the low-carbon economy, certified carbon

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

emissions have basic attribute of financial products. It can study the price discovery function between international oil price and the carbon trading price.

International oil price and carbon trading price are likely to interact on another, and it maybe has the two-way spillover effect. The spillover effect involves the mean spillover effect and the fluctuation spillover effect, the granger causality between two variables bases on the first order moment mainly refers to the mean spillover effect, and it studied the co-integration relationship between the carbon trading market futures price and its spot price [9]. The granger causality basing on the second order moment mainly refers to the fluctuation spillover effect, and it is less common in the literature. On the basis of the existing literature, through the multivariate GARCH model empirical analysis, it would study the spillover effect and the price discovery functions between the international oil price and carbon trading market price.

2. VARIABLE SELECTION

The exploration of regional carbon sinks as well as carbon emissions and the implementation of carbon trading offset are not only the foresight-and-sagacity action responding to global challenges and taking on emission reduction responsibilities, but the practical strategy of adapting to rapid economic increases, reducing pressure on ecological environment protection, and implementing the scientific outlook on development. The paper indicates that China is ready for carrying out regional carbon trading based on the objective analysis of national conditions and the new way exploration. “Carbon ticket” oriented carbon trading mode is a dare-to-be-first innovation and practice with operational market base and technology base.

At present, the NYMEX crude oil futures contract, especially WTI has become one of the most active futures varieties in the world commodity futures trading markets. The fragile balance relationship in the oil market always is affected by a variety of factors, and the reaction to the futures markets always is reflected in WTI, and then price would affect world kinds of futures markets. Therefore, it selected the west Texas intermediate (WTI) oil prices to study spillover effects to the carbon market, and noted as P_{WTI}. Chicago Climate Exchange is North America's largest and longest running greenhouse gas emission reduction program. From 2003 through 2010 CCX operated as a comprehensive cap and trade program with an offsets component. In 2011 CCX launched the Chicago Climate Exchange Offsets Registry Program to register verified emission reductions based on a comprehensive set of established protocols. As the world most active voluntary carbon trading market, CCX is sensitive and fragile in the carbon trading.

Due to the geographical and political factors, the relationship between WTI and CCX is close; the mutual influences also are significant. It selected the CCX carbon market price, and noted as P_{CCX}, which was monthly futures prices from 2004 to 2009. Through ADF unit root test it had found that the price of WTI and Chicago carbon trading market ware not accord with the serial stable hypothesis, and first order difference of two series had meet the 99% significant level of unit root test. So in the GARCH analysis, first order differences of the two markets price were taken which ware noted as DP_{WTI} and DP_{CCX} respectively. In order to depict first-order difference sequences statistical characteristic of international petroleum and CCX price, the basic statistical results ware reported in table 1.

Table 1: Statistic Features Of The Market Prices

Statistics	DP_{WTI}	DP_{CCX}
Mean	0. 566	-0.011
Standard Deviation	7.098	0.630
Skewness	-1.436	-0.584
Peak Value	6.115	7.507
Q(2)	52.607(0.000)	39.976(0.000)
Jarque-Bera	53.107(0.000)	64.119(0.00)
ADF	-12.455(-3.529)	-6.258(-3.537)

Note: Q (10) is the statistics for Ljung - Box test, in order to test the autocorrelation coefficient of the price sequence and price square sequence lag 1-10 orders whether is zero. If the sequences were not auto-correlate, two statistics both obey $\chi^2(10)$. Jarque - Bera statistics belongs to the normal distribution test, and the data in brackets mean the probability level. ADF statistics for unit root test is used to test the sequence stability.

From table 1, it was known that the international petroleum price fluctuation was greater than the price of CCX. Jarque-Bera statistics indicated that the CCX carbon trading price (namely DP_{CCX}) and west Texas intermediate (that is, DP_{WTI}) were skewness, kurtosis and non-normal significantly at 1% level. Q(10) statistic analysis the 10 lag phases of autocorrelation coefficient whether were 52.607 and 39.976, and the result showed that the DP_{WTI} and DP_{CCX} ware auto-correlate significantly at 1% level. ADF unit root test in two series found that first order difference of international petroleum price and carbon market price was significant on the 99% level.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3. RESULTS OF EMPIRICAL RESEARCH

In econometrics, Auto-Regressive Conditional Heteroskedasticity (ARCH) models are used to characterize and model observed time series. They are used whenever there is reason to believe that, at any point in a series, the terms will have a characteristic size, or variance [10]. In particular ARCH models assume the variance of the current error term or innovation to be a function of the actual sizes of the previous time periods' error terms: often the variance is related to the squares of the previous innovations. Such models are often called ARCH models, although a variety of other acronyms are applied to particular structures of model which have a similar basis [11]. ARCH models are employed commonly in modeling financial time series that exhibit time-varying volatility clustering, i.e. periods of swings followed by periods of relative calm. If an autoregressive moving average model (ARMA model) is assumed for the error variance, the model is a generalized autoregressive conditional heteroskedasticity (GARCH) [12].

Volatility spillover refers to the volatility of the market not only may be affected by the fluctuation of the prophase itself may be affected by other market fluctuation, the influences between two markets is called volatility spillover effect. The present empirical study used the single variable GARCH model (university GARCH), but the single variable model could not depict the volatility spillover effect of exogenous variables. It adopted multivariate GARCH model, introduced international petroleum price as exogenous variables, used causality relationship test on the residual square sequence to study the price of CCX volatility spillover effect. In the empirical study of the single variables GARCH (university GARCH) model was used, but not a single variable model depicts exogenous variables to this market volatility spillover effect. It studied the mean and fluctuation spillover effect between the international petroleum price and the price of the CCX carbon trading by using binary VAR and multivariate GARCH model.

Introduction of the international oil prices as the exogenous variable, by testing the causality in the residual square sequences, it studied the spillover effect of the CCX carbon trading price. Because DP_{CCX} sequence has "peak thick tail" and volatility clustering characteristics, and existed obvious autocorrelation relationship, it considered using GARCH model. In that case, the GARCH (p, q) model (where p is the order of the GARCH terms σ^2 and q is the order of the ARCH terms ϖ^2) is given by

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varpi_{t-i}^2 + \sum_{j}^{p} \beta_j \sigma_{t-j}^2 \quad (1)$$

Generally, when testing for heteroskedasticity in econometric models, the best test is the White test. However, when dealing with time series data, this means to test for ARCH errors (as described above) and GARCH errors.

Assumed that carbon trading price and international oil prices' range of change are y_t and x_t respectively, the mean equation was binary VAR model, and the GARCH (1, 1) model was explained by past values. The mean and variance equation as the following equation (2) and (3):

$$y_t = \sum_{i=1}^{n} \alpha_{1i} y_{1,t-i} + \sum_{j=1}^{n} \pi_{1j} x_{1,t-j} + \varepsilon_t \quad (2)$$

$$\sigma_t^2 = \varpi + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (3)$$

Model (2) was the binary VAR model, x_t stranded for fluctuations of the international petroleum price and noted as DP_{WTI} which was the exogenous variables. It mean the lag order number of the equation, ε_t was the residual sequence. The (1, 1) in GARCH (1, 1) separately refer to an ARCH item and a GARCH item. In the conditional variances equation (3), ϖ mean the constant item, σ_{t-1}^2 was the GARCH item. In addition, the model about the fluctuation spillover effect from CCX price to the international petroleum price was symmetric.

The GARCH model was considered first in the empirical analysis of the spillover effects between DP_{CCX} and DP_{WTI} sequence. As the price formation process was different in different market, in order to capture the relationship between the two market prices, it built the mean equations as the (1) type first, and the variance equation as the (2) type. According to the principle of AIC and SC, the best lag order was 1 in the binary VAR equation. Using maximum likelihood method, joint estimating the model (1) and (2), and using Marquardt parameter estimation in the iterative process, it got the estimation results and standardized residual test results, see table 2.

Journal of Theoretical and Applied Information Technology
15th December 2012. Vol. 46 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 2 : Estimated Results Of The Spillover Effect Between CCX And WTI

The mean function	α	π		
y_t	0.326(0.001)	-0.019(0.033)		
x_t	0.366(0.001)	1.522(0.000)		
The variance function	ϖ	α	β	
y_t	0.015(0.068)	0.725(0.026)	0. 451(0.007)	
x_t	0.333(0.757)	-0.137(0.233)	1.173(0.000)	
Model test	R^2	AIC	SC	DW
y_t	0.089	1.428	1.589	2.188
x_t	0.273	6.337	6.498	2.065
Standard residual test	Q(10)	LM(1)检验		
y_t	6.586(0.764)	0.081(0.777)		
x_t	13.661(0.18	0.805(0.372)		
Wald test				test results
null hypothesis：it is no spillover effects between CCX and WTI, $H_0 : \alpha_{12} = \beta_{12} = 0$				67.559(0.000)

Note: The data in brackets mean the Prob. statistical level. The Wald-test chooses F estimated value.

The first part in the form was about the parameters estimate results of the mean function. It could be found the CCX carbon trading price was influenced not only by its early price, but by the international oil prices, the coefficient were 0.326 and 0.019 respectively. The international oil price would lead CCX carbon trading price to drop.

The second part of the form was for the parameter estimation results of the variance function. And the fluctuation spillover effect from WTI to the CCX carbon trading price was remarkable. Due to the value of $\alpha + \beta$ was slightly higher than the 1; the impact from oil price of WTI to the CCX carbon trading price was sustained. But, in studying the spillover effect from the CCX carbon trading price to WTI oil futures prices, it found that GARCH (1, 1) model couldn't reflect effectively the spillover effect from American carbon trading price to the international petroleum price.

The third part was the test result about the model. Although R^2 was low, but it's not the only standard in test the effectiveness of the equation. *DW* Test was 2.188 which illustrated the auto-correlation in residual of the equation had been eliminated basically. *AIC* and *SC* values ware relatively low which ware 1.428 and 1.589 respectively in the GARCH (1, 1)model. And it mean that the results of the equation ware relatively ideal. In test of standardization residual to the equation, it choose Ljung-Box statistics and Lagrange Multiplier Test (LM Test) F statistics. The results showed that Q (10) and LM (1) all passed the original hypothesis; residual sequences had no longer existed serial auto-correlation and heteroskedasticity. The estimate results of variance equation was very ideal, the model to estimate the spillover effect from WTI to CCX was scientific completely.

In the last part, the Wald test was used to test the coefficients. The results mean that the coefficients α_{12} and β_{12} were not 0, and the null hypothesis that it did not exist fluctuation spillover was rejected.

The spillover effect from the WTI oil price to the CCX carbon trading price was significant. And the spillover effect from the WTI oil price to the CCX carbon trading price was significant. WTI oil price had the significant price discovery function to the CCX carbon trading price. The volatility of CCX carbon trading price was influenced itself, at the same time, was influenced by the volatility of WTI oil price.

Because the model of GARCH (1, 1) couldn't explain fluctuation spillover effect from the price of CCX to the WTI oil price, it used the TGARCH model, EGARCH model and PGARCH model to estimate the fluctuation spillover effect from the WTI oil price to the CCX carbon trading price.

TGARCH model: the Threshold GARCH (TGARCH) model is similar to GJR GARCH, and the specification is one on conditional standard deviation instead of conditional variance [13]:

$$\sigma_t = K + \delta\sigma_{t-1} + \alpha_1^+ \varpi_{t-1}^+ + \alpha_1^- \varpi_{t-1}^- \quad (4)$$

Where $\varpi_{t-1}^+ = \varpi_{t-1}$ if $\varpi_{t-1} \succ 0$, and $\varpi_{t-1}^+ = 0$ if $\varpi_{t-1} \le 0$ .Likewise, $\varpi_{t-1}^- = \varpi_{t-1}$ if $\varpi_{t-1} \le 0$, and $\varpi_{t-1}^- = 0$ if $\varpi_{t-1} \succ 0$.

EGARCH, the exponential general autoregressive conditional heteroskedastic (EGARCH) model is another form of the GARCH model. Formally, an EGARCH (p, q) [14]:

$$\log\sigma_t^2 = \omega + \sum_{k=1}^{q} \beta_k g(Z_{t-k}) + \sum_{k=1}^{p} \alpha_k \log\sigma_{t-k}^2 \quad (5)$$

Where, $g(Z_{t-k}) = \theta Z_t + \lambda(|Z_t| - E(|Z_t|))$, σ_t^2 is the conditional variance, ω , β , α , θ and λ are coefficients, and Z_t may be a standard normal variable or come from a generalized error distribution. The formulation for $g(Z_t)$ allows the sign and the magnitude of Z_t to have separate effects on the volatility. This is particularly useful in an asset pricing context. Since $\log\sigma_t^2$ may be negative there are no (fewer) restrictions on the parameters.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The P-GARCH model: the periodic GARCH model proposed by Bollerslev and Ghysels [15]. Drawing on the similarity of equation (3) to an ARMA (p, q) model and the theory of periodic ARMA processes, Bollerslev and Ghysels develop a GARCH specification with time-varying coefficients. The P-GARCH parameterization can then be written.

$$\sigma_t=\omega_{s(t)}+\sum_{i=1}^{q}\alpha_{is(t)}\varepsilon_{y-i}^2+\sum_{j=1}^{p}\beta_{js(t)}\sigma_{t-1}$$

(6)

Where $s(t)$ refers to the stage of the periodic cycle at time t.

Analysis of the results in table 3, it found that C(4) coefficient was negative in the TARGH model, and the coefficients in EGARCH and PGARCH models ware not significant, it was no significant fluctuation spillover effect from the CCX price to the WTI price.

Table 3 : Estimated results of the spillover effect from CCX to WTI

Mean function	α		π	
TARCH	0.382(0.001)		1.633(0.221)	
EGARCH	0.427(0.000)		1.623(0.181)	
PGARCH	0.431(0.001)		1.636(0.200)	
the variance function	C(3)	C(4)	C(5)	C(6)
TARCH	0.952	-0.091	0.020	1. 071
	(0.103)	(0.228)	(0.878)	(0.000)
EGARCH	3.487	-0.139	-0.252	0.053
	(0.196)	(0.645)	(0.247)	(0.948)
PGARCH*	5.512	-0.142	-0.997	-0.242
	(0.582)	(0.295)	(0.009)	(0.688)

Note: The data in brackets mean the Prob. statistical level.*PGARCH also included coefficient C (7) =0.793(0.3558).

On the basis of previous study results, it found that the WTI oil price was the factors that affected the CCX carbon trading price. The price of CCX not only was influenced by itself, but influenced by the oil price of WTI. The oil price of WTI had significant price discovery function to the carbon trading price of CCX. But the impacts of the CCX carbon trading price on the WTI oil price are not significant.

4. CONCLUSIONS

As an important global voluntary carbon trading market, the relationship of carbon emissions supply and demand in CCX is weak, so the study on the influence factors of CCX markets can guide the development of CCX and other voluntary carbon trading markets system. With oil prices rising, voluntary carbon trading market prices will fall back, which will lead to carbon emissions transaction enthusiasm drop and efficiency of market resources allocation reduce, which is disadvantageous to the development of the carbon market. Now China is in the process of rapid industrialization and urbanization, so it is in an urgent need of energy resources and is also faced with severe environmental pollutions. And hence, it is urgent to conserve energy and cut emissions, so the need for carbon transaction market arises. It is of paramount importance to make an in- depth analysis of the status- quo and formation mechanism of China's carbon transaction market, and promote emission cut, industrial readjustment and transformation of economic development mode. The path of low carbon development with Chinese characteristics should be blazed gradually and step-by-step. Regional carbon ticket transaction pilot is suggested to be carried out under the guidance of policies, when overall feasibility study on virtual trading steps is demonstrated. Moreover, the market transactions should be standardized gradually when conditions are mature and policy system is refined, and meanwhile it should be promoted in a larger area to provide examples for implementation of national carbon trading. It will set up voluntary carbon trading market mechanism and try to perfect pricing process second level CDM market in China, so it should consider the influence and impact of the international oil price to the carbon trading market. However, due to policy uncertainties caused by the current negotiation for the future international climate regime, and also inflicted by the European sovereign debt, the international carbon market is stalled. More specific emission reduction target should establish. Comparing with the more developed carbon market in other developed countries, sophisticated subsidiary system such as monitoring system, law system, and professional experts training are in urgent need for establishing efficient and professional trade market , also striving for the pricing right . The national emission reduction market may have a hopeful development with the forthcoming industrial and regional reduction target establishment.

ACKNOWLEDGEMENTS

We wish to thank Dr. Peng Zhou of Nanjing University of Aeronautics and Astronautics many helpful discussions. We are thankful and acknowledge the support under China EEE. This work was supported by scientific research fund project XJ201235of QuFu Normal University.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

REFERENCES:

[1] R. Kawase, Y. Matsuoka, J. Fujino, "Decomposition Analysis of CO2 Emission in Long- term Climate Stabilization Scenarios", *Energy Policy*, Vol.34, No.15, 2006, pp.2113-2122.

[2] S. Y. Wang, D. Li, "The relationship between Carbon transaction volume, carbon trading price and the international oil price", *Price theory and Practice*, No.4, 2011, pp.52-53.

[3] J. D. Hamilton, "This is what happened to the oil price-macro economy relationship", *Journal of Monetary Economics*, Vol.38, No. 1996, pp.215-220.

[4] L. Kilian, C. Park, "The Impact of Oil Price Shocks on the U.S. Stock Market", *International Economic Review*, Vol.50, No.4, 2009, pp.1267-1287.

[5] S. Y. Wang, D. Li, "The Spillover Effects on Petrochemical industrial concentration of International Oil Price", *Energy Procedia*, No.5, 2011, pp.2444-2448.

[6] S. Hammoundeh, H. Li, B. Jeon, "Causality and volatility spillovers among petroleum prices of WTI, gasoline and heating oil in different locations", *North American Journal of Economics and Finance*, Vol.14, No.1, 2003, pp.89 - 114.

[7] J. D. Hamilton, "This is What Happened to the Oil Price-macro Economy Relationship", *Journal of Monetary Economics*, Vol.38,No.2, 1996, pp.215-220.

[8] L. X. Dong, Y.S. Zhang, "The research on the spillover effects between domestic and foreign crude oil ", *Journal of Chinese science*, No.12, 2006, pp.120-127.

[9] T. T. Qi, W. LU, "An Empirical Research on Price Discovery of CERs Spot Market and Futures Market", *Journal of Beijing institute of technology* , Vol.11, No.6, 2009, pp.71-77.

[10] R.F. Engle, F. Robert, "Autoregressive Conditional Heteroscedasticity with Estimates of Variance of United Kingdom Inflation", *Econometrica*, Vol.50, No.4, 1982, pp.987-1008.

[11] T. Bollerslev, K. Chou, "ARCH modeling in finance: A review of the theory and empirical evidence", *Journal of Econometrics*, Vol.52, No.1, 1992, pp.5–59.

[12] R. F. Engle, V.K. Ng, , "Measuring and testing the impact of news on volatility", *Journal of Finance*, Vol.48 , No.5, 1991, pp.1749-1778.

[13] M. Zakoian, "Threshold Heteroscedastic Models", *Journal of Economic Dynamics and Control*, Vol.18, No.5, 1994, pp.931-955.

[14] D. B. Nelson, , "Conditional heteroskedasticity in asset returns: A new approach", *Econometrica*, Vol.59, No.2, 1991, pp.347-370.

[15] T. Bollerslev, Ghysels, "Periodic autoregressive conditional heteroscedasticity", *Journal of Business & Economic Statistics*, Vol.14, No.2 1996, pp.139-151.