Constant vs. Time-varying Hedging Effectiveness Comparison for CO_2 Emissions Allowances: the Empirical Evidence from the EU ETS

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Abstract: - In recent years emissions allowances markets have become the most promising and quickly growing markets in the global commodities markets. In this paper, we estimate constant and time-varying optimal hedge ratios (OHR) and hedging effectiveness between spot and futures for CO_2 emissions allowances by choosing the two-step EG, ECM, ECM-GARCH, and modified ECM-GARCH techniques. The empirical results show that price series between spot and futures contracts with different maturities exhibit significant cointegration relation, the error corrections and previous price movement significantly affect the optimal hedge ratios, and the hedging effectiveness (HE) by using constant hedge ratios from the ECM method has slightly better than HE from the two-step EG method. The optimal hedge ratios from the ECM-GARCH and modified ECM-GARCH method exhibit strongly time-varying trend, and then the hedging effectiveness by using time-varying hedge ratios from the ECM-GARCH and modified ECM-GARCH method are significantly better than HE by constant hedge ratios. The hedging effectiveness from the modified ECM-GARCH methods is highest among the hedging portfolio returns by using the above four methods.

Key-Words: - Emissions allowances, hedge ratio, hedging effectiveness, ECM-GARCH, modified ECM-GARCH

1 Introduction

Greenhouse gas (GHS) emissions are an ever-creasing hot topic in the 21st century for the alarming phenomena of global warming and climate deterioration. Most of scientists and politicians generally accept emissions trading scheme is a cost-effective scheme. Since 2005, several emissions allowances markets have formally entered into oper -ation in the European Union emissions trading scheme (EU ETS). The right to emit a particular amount of CO_2 is given by a specific property in the EU ETS, it becomes a tradable and valuable commodity as same as the other physical commodities. In recent years emissions allowances have become the most promising and quickly growing markets in the global commodities markets. According to research report on state and trend of carbon market in 2011 by the World Bank, the total value of the global carbon markets grew 6% to US $144 billion (or €103 billion) until 2010, its trade volume attained 8.7 billion tons CO_2. Emissions allowances markets will become the largest commodity markets in the futures.

Several empirical results show that spot and futures prices for CO_2 emissions allowances are shown to contain a dynamic behaviour [1-4].Benz and Truck (2006) propose emissions allowances prices are directly determined by the expected market scarcity which is induced by the current demand and supply [1]. Seifert et al (2008), Benz and truck (2009) propose dynamics behavior of CO_2

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spot price [2-3]. Seifert et al (2008) find CO_2 spot prices do not follow any seasonal patterns, they exhibit a time- and price-dependent volatility structure in the pilot phrase. Benz and truck (2009) present the short-term spot price behaviour of carbon dioxide (CO2) emission allowances of the new EU-wide CO2 emissions trading system. Chang and Wang et al. (2012) propose a new N-factor affine term structure model for CO2 futures price and their empirical results show that CO2 futures prices and convenience yields follow significant mean-reversion process [4].

In many empirical results, cointegration is prevalent and powerful econometrics technique for investigating multivariate time-series and dynamics in the system, it provides optimal hedge ratio (OHR) and hedging portfolio efficiency between spot and futures assets. There is cointegration relationship between electrical energy consumption and economic growth taking into account industry structure changes and technical efficiency [5].

Derivatives markets for emissions allowances are of emerging financial markets. It is significant to examine the possible cointegration relationship in prices between spot and futures for CO_2 emissions allowances. In recent years, market efficiency, risk management and derivatives pricing has become the most fashionable topic for the scholars, financial institutions, hedgers and other market practitioners. Daskalakis and Psychoyios (2009) develop an empirical and theoretical valid framework for the pricing and hedging of intra-phase and inter-phase futures and options for CO_2 emissions allowances [6]. Montagnoli and Vries (2010) exhibit that Phase I-the trial and learning period was inefficient, Phase II shows signs of restoring market efficiency by Variance ratio tests [7]. Milunovich and Joyeux (2010) examine the issues of market efficiency and price discovery in CO_2 emissions allowances futures markets under the EU ETS, their finding indicate the spot and futures markets share information efficiently and contribute to price discovery jointly [8]. Chevallier (2010) analyzes the modelling of risk premium in CO_2 allowances spot and futures prices, and he finds time-varying risk premium in CO_2 spot and futures prices, positive relationship between risk premium and time-to-maturity futures contracts[9]. Zhou and Mi calculate energy consumption and CO_2 emissions in the year 2010-2030 by taking Chinese industrial structure and energy consumption in each industry into account, and their empirical results show CO_2 emissions can be reduced 1.95 billion tons in 2030 if clear energy account for 20% of total energy consumption [10]. Hajek and Olej present air quality modeling by using various structures of Kohonen's self-organizing feature maps and the classification by Learning Vector Quantization neural networks, and its modeling generates well-separated clusters and has good generalization ability as well [11].

Compared with the analysis of the above mentioned papers, this paper has three greatest innovations. The first innovation is to examine co-integration tests of prices series between spot and futures for CO_2 emissions allowances. The second innovation is to propose the optimal hedging ratio and make flexible portfolio policy by co-integrated assets for CO_2 emissions allowances. The third innovation is to compare risk reduction of constant and dynamic hedging portfolio between spot and futures contracts with different maturities. The optimally dynamics hedging ratio and hedging efficiency will allow the companies, investors and hedgers to realize efficient trading strategies, risk management and to make the right investment decisions in the CO_2 emission allowances markets.

Since the seminal work of Engle & Granger (1987), co-integration has become the most popular tool of time-series econometrics [12]. There are many methods of cointegration tests, such as Augmented Dickey Fuller (ADF), two-step Engle & Granger model (EG), error correction model (ECM), generalized autoregressive conditional heteroskeda-sticity (GARCH), BGARCH, ECM-GARCH, and so on. In order to examine cointegrated relations between spot and futures contracts for CO_2 emissions allowances, we choose two-step EG, ECM, ECM-GARCH, and modified ECM-GARCH tests techniques.

The remainder of the article is organized as follows. Section 2 describes date sample source and cointegration tests. Section 3 presents constant hedge ratio using cointegration theory and examines their empirical results in the CO_2 spot and futures markets. Section 4 gives the optimally dynamic hedging ratios and adjusts portfolio policy for emission allowances assets. Section 5 proposes empirical hedging effectiveness comparison of constant and time-varying hedging portfolio. Section 6 concludes.

2 Date Description and Cointegration Test

2.1 Date Description

There has existed two phases: the Pilot phase (2005-2007) and the Kyoto phase (2008-2012). Various exchange markets introduce different emphasis on spot and futures trading products for CO_2 emissions allowances. In this paper, we choose empirical date samples are from the most liquid and largest CO_2 spot and futures exchange platform in the EU ETS. The spot trading in Bluenext exchange was introduced on June 24, 2005. Now Bluenext exchange has become the most liquid platform for CO_2 spot trading. The futures trading in European Climate Exchange (ECX) which is merged by ICE on August 2010, has started on April 22, 2005. Now ECX (ICE) has become the most liquid and largest platform for CO_2 futures and options trading in the world.

Since European Union implemented banking and borrowing restrictions, spot prices for CO_2 emissions allowances have been decreasing towards zero from October 2006 to December 2007 [9]. Date samples are from spot and futures contracts with different maturities in the Kyoto phase. One European Union allowance (EUA) has the right to emit one tone CO_2 into the atmosphere under the EU ETS. The minimum trading volumes for each futures contract are 1,000 tons CO_2 equivalent. We choose time-serial daily settlement price for EUA futures contracts with different delivery dates going from December 2010 to December 2014. Since the trading of futures contracts with vintages December 2013 and December 2014 were started on April 8, 2008. Considered the continuity and availability of numerical samples, we select the date samples cover the period from April 8, 2008 to December 20, 2010 in the Kyoto phrase.

2.2 Cointegration Test

In the following figure 1, Here S denotes spot price for CO_2 emissions allowances, F_1 denotes the closest to maturity of EUA futures contract for CO_2 emissions allowances, F_2 denotes the second closest to maturity of EUA futures contract, and so on. Seen from in the figure 1, we find price series both spot and futures contracts with different maturities exhibit strongly time-varying trend in the whole sample period. We find spot and futures prices for emissions allowances exhibit similar upwards and downwards jump motion trend, accordingly prices series both spot and futures may exhibit co-integrated relations.

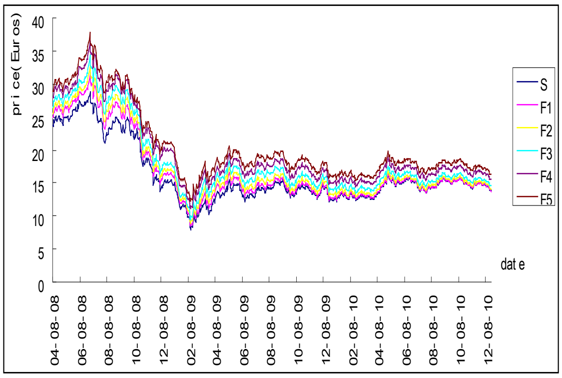

Figure 1: Price series both spot and futures for EUA emission allowances

The Augmented Dickey-Fuller (ADF) test used to examine the presence of unit roots and co-integrated relations of price series in the whole sample period. The ADF statistical values in price series and first-difference series for the logarithms of each variable are shown in the following table 1. ADF statistical values in price series both spot and five futures contracts are all bigger than the critical value at the confidence level 90%, the price series both spot and five futures are non-stationary series. ADF test values in the first difference series both spot and five futures are far less than critical value at the confidence level 99%, first difference series both spot and futures are stable series. Accordingly we propose prices series between spot and futures contracts with different maturities exhibit co-integrated relations. The above those results provide the theoretical basis to make the optimal hedging ratio and hedging efficiency.

Table1 ADF tests for the logarithms of each variable

	ADF test statistics		
variable	S	F_1	F_2
Price series	-1.8167	-1.7173	-1.6936
1st difference series	-20.3654	-20.0190	-19.9637
variable	F_3	F_4	F_5
Price series	-1.6565	-1.5023	-1.4642
1st difference series	-19.8262	-20.0270	-19.9632

Note: under the confidence level 99%, 95%, 90%, the critical values of ADF test with intercept are -3.4396, -2.8655, -2.5689.

3 Constant Hedge Ratio Using Co-integration

Many empirical results show spot prices and futures prices for emissions allowances show time-varying trend, accordingly spot and futures prices series exhibit non-stationary feature [1-5]. The prices spreads between spot and futures for CO_2 emissions allowances are determined by their dynamic relationship. In general, high correlation in returns of two underlying assets is important for short-run price relationships, but high correlation in assets returns does not necessarily imply high co-integration in prices. Cointegration is a technique to measure long-term dynamic equilibrium relationship between two underlying assets prices generated by historical market information and behaviours feature.

3.1 The Estimation of Constant Hedge Ratio

Based on the hedging theories, naive hedging strategy suggests that to minimize exposure, a bona fide hedger who hold long position CO_2 spot should sell a unit of CO_2 futures at time *t*, and buy the CO_2 futures back when he sell a unit of CO_2 spot. We consider a bona fide hedger can hold the assets portfolio of c_s units long position spot and c_f units short position futures, and the assets portfolio returns ΔV_h is equal to

$$\Delta V_h = c_s \Delta s_t - c_f \Delta f_t \quad (1)$$

Where s_t, f_t is the nature logarithms in price both spot and futures for CO_2 emissions allowances at time t, $\Delta s_t = s_t - s_{t-1}, \Delta f_t = f_t - f_{t-1}$. Accordingly assets portfolio risk is equal to as follows:

$$\mathrm{var}(\Delta V_h) = c_s^2 \,\mathrm{var}(\Delta s_t) + c_f^2 \,\mathrm{var}(\Delta f_t) - 2c_s c_f \,\mathrm{cov}(\Delta s_t, \Delta f_t) \quad (2)$$

We attain the minimum variance of hedge ratio by minimizing the risk of hedge portfolio [13].

$$h^* = \frac{c_f}{c_s} = \frac{\mathrm{cov}(\Delta s_t, \Delta f_t)}{\mathrm{var}(\Delta f_t)} \quad (3)$$

3.2 Constant Hedging Ratio Using Cointegra -tion

Alexander (1999) proposes when spreads are mean-reverting, prices are cointegrated, and attain optimal hedging policy of Spot-futures financial assets using cointegration theory [14]. Engle and Granger (1987) propose two-step examine technique, EG method is to perform an ordinary least squares regression, and then test the residuals for stationarity [12].

$$\begin{aligned} \Delta s_t &= a + b\Delta f_t + \xi_t \\ \xi_t - \xi_{t-1} &= \omega \xi_{t-1} + \mu_t \end{aligned} \quad (4)$$

Where ξ_t is the residual, μ_t is a Gaussian disturbance. Engle and Granger (1987) demonstrate that the error term ξ_t must be mean reverting if two underlying prices exhibit cointegration [12]. A conventional approach to estimate h* relies upon the simple linear regression method. We apply the daily settlement price to estimate the relationship b in spot-futures prices for emissions allowances. The estimated coefficient is the estimated optimal hedge ratio. Thereby the optimal hedge ratio from two-step EG model remains constant.

Since the price series both spot and futures for emissions allowances are non-stable, If prices series both spot and futures exhibit cointegrated relationship, the estimated coefficient b is biased, thereby the optimal hedge ratio is not optimal. The two-step EG approach ignores many historical market information variables. Notably previous prices movements in the spot and futures CO_2 markets and the co-integrated relations in prices between spot and futures contracts may affect optimal hedge ratio. Based on the cointegration theory, Peng and Ye (2007), Fang and Chen (2008) proposes the optimal hedge ratio by using error correction model (ECM) [15-16]. ECM is a dynamic model, which is based on correlations in returns of two underlying assets, ECM reflects that short-term deviation is away from the long-term equilibrium. Accordingly ECM considers non-stationary in prices between spot and futures, long-run equilibrium, short-run dynamics. ECM takes the form:

$$\Delta s_t = \alpha_s + \sum_{i=1}^{m} \beta_{si} \Delta s_{t-i} + \sum_{j-1}^{n} \gamma_{sj} \Delta f_{t-j} + \theta_s z_{t-1} + \varepsilon_{st} \quad (5)$$

$$\Delta f_t = \alpha_f + \sum_{i=1}^{m} \beta_{si} \Delta s_{t-i} + \sum_{j=1}^{n} \gamma_{fj} \Delta f_{t-j} + \theta_f z_{t-1} + \varepsilon_{ft} \quad (6)$$

Where Δ denotes the time series difference of each variable, $z_t = f_t - s_t$ denotes the cointegration vector, and the lags lengths and coefficients are determined by ordinary least squares regression. If z is large and positive, this will have a negative effect on Δs, for $\theta_s < 0$ and z will decrease, the effect on Δf is positive for $\theta_f > 0$, and f_t will increase, and errors are corrected in this way. When spot-futures prices for emissions allowances are cointegrated, the error-correction model will capture dynamic correlations and causalities between two prices returns. The above ECM can also be written as the following forms [15-16]:

$$\Delta s_t = \alpha + h\Delta f_t + \sum_{i=1}^{m} \beta_i \Delta s_{t-i} + \sum_{j=1}^{n} \gamma_i \Delta f_{t-j} + \theta z_{t-1} + \varepsilon_t \quad (7)$$

3.3 Empirical Results of Constant Hedge Ratio

Shown in the following table 2, the residuals statistical value of ADF test in the two-step EG model is far less than the critical value at the confidence level 99%, they indicate the residuals from EG model exhibit steady. Price series between spot and five futures contracts exhibit cointegrated relations. Seen from the following table 2, we propose fitting goodness R^2 and z-statistic values are all larger, accordingly the fitting results from the EG and ECM are well. Obviously we can see constant hedge ratios from the ECM model are all bigger than hedge ratios from the EG model, the estimated coefficients of error corrections vector are significant, these empirical results show the error corrections affect the optimal hedge ratio, and previous prices movement both spot and futures for emissions allowances significantly affect the optimal hedge ratio. The hedge ratio of long-maturity futures is bigger than the hedge ratio of short-maturity futures.

Table 2 The empirical results of constant hedge ratio from the EG and ECM model

Cointegration test		F_1	F_2	F_3
	h^*	0.9716	0.9939	1.0082
	z	90.83	102.49	95.51
EG	R^2	0.923	0.938	0.929
	ξ *ADF*	-22.257	-26.006	-24.181
	h^*	0.9869	0.9996	1.0107
	z	119.41	119.89	104.35
ECM	R^2	0.955	0.955	0.942
Cointegration test		F_4	F_5	
	h^*	1.0667	1.1252	
	z	69.89	68.04	
EG	R^2	0.876	0.870	
	ξ *ADF*	-22.960	-22.420	
	h^*	1.0688	1.1265	
	z	71.74	69.07	
ECM	R^2	0.884	0.876	

Note: 1.EG, ECM denotes two-step test of Engle and Granger and error correction model, h^* is constant hedge ratio.

2. $\xi_t = \Delta s_t - (a + b\Delta f_t)$, ξ -ADF denotes the statistic values of ADF test for the residuals. Under the confidence level 99%, 95%, 90%, the critical values of ADF test with intercept are -3.4396, -2.8655, -2.5689.

3.The above table2 reports estimated coefficients by the following ECM equation:

$$\Delta s_t = \alpha + h\Delta f_t + \beta_1 \Delta s_{t-1} + \gamma_1 \Delta f_{t-1} + \theta z_{t-1} + \varepsilon_t$$

4 Time-varying Optimal Hedge Ratio Using Cointegration

In the above two cointegration tests, ADF and ECM are assumed the residuals have constant variances and covariances. Bollerslev (1990), Kroner and Sultan (1993), Lien, Tse and Tsui (2002), Lien and Yang (2008) estimate optimally time-varying hedge ratio by using the BGARCH model [17-20]. Kroner and Sultan (1993), Koutmos and Pericli (1998, 1999), Lien and Tse (1999), Peng and Ye (2007) propose time-varying hedging by using the bivariate error-correction GARCH model[15,21-23]. Since cointegration can measure long-run co-movement in prices, hedging methodologies using cointegration theory for CO_2 emissions allowances may be more effective in the long term.

4.1 The Estimation of Time-varying Hedge Ratio

If spot and futures prices for CO_2 emissions allowances both change by the same amount, the hedgers will not change net position, and the hedge ratios are constant. In the realistic emissions allowances markets, spot and futures prices do not always move at the same speed, the wise hedger can adjust hedging net position by the information set at the time *t-1*, accordingly the hedge ratios are dynamic. We consider a bona fide hedger within a one-period framework from time *t-1* to time *t* reducing the risk exposure, the hedger assumes short positions for CO_2 futures contract. Based on the information set ϕ_{t-1}, the hedgers have non-tradable spot position Q at time *t-1* and sell X futures contracts, let $h_{t-1} = X/Q$. The returns of hedging portfolio in the period *(t-1, t)* are equal to

$$R_{ht} = \Delta s_t - h_{t-1}\Delta f_t \quad (8)$$

Where h_{t-1} is hedge ratio at the time *t-1*, the risk of hedging portfolio is measured by the conditional variance at the information available set ϕ_{t-1}. The returns of variance are equal to

$$\operatorname{var}(R_{ht}|\phi_{t-1}) = \operatorname{var}(\Delta s_t|\phi_{t-1}) + h_{t-1}^2 \operatorname{var}(\Delta f_t|\phi_{t-1}) - 2h_{t-1}\operatorname{cov}(\Delta s_t, \Delta f_t|\phi_{t-1}) \quad (9)$$

The hedgers choose the optimal hedge ratio h* to minimize the variance risk given by the $\operatorname{var}(R_{ht}|\phi_{t-1})$.

$$h^* = \frac{\operatorname{cov}(\Delta s_t, \Delta f_t|\phi_{t-1})}{\operatorname{var}(\Delta f_t|\phi_{t-1})} \quad (10)$$

Where cov(.) is the covariance operator. When spot and futures markets generate new information, the optimal hedge ratios show time-varying trend.

4.2 Dynamic Optimal Hedge Ratio Using Co-integration

The early research results show spot and futures prices for CO_2 emissions allowances are directly determined by the expected market scarcity, which is induced by the change of emissions regulation policy, extreme weather, energy price, abatement technology progress etc[1-2][9]. Benz and truck (2009) provide spot volatility behaviour for emissions allowances is of dynamics trend by GARCH model in the pilot phase. In realistic CO_2 emissions allowances markets, the conditional covariance matrix in spot-futures prices show actually time-varying behaviours. Accordingly optimal hedge ratios exhibit time-varying trend rather than constant trend. The following section, the hedgers can attain optimally time-varying hedge ratios and hedging efficiency by using ECM-GARCH and modified ECM-BGARCH model.

We can estimate optimally dynamic hedge ratios by the bivariate GARCH incorporated the error correction term. Thereby the bivariate ECM-GARCH structure look as follows [13-14,16, 19-20].

$$\Delta s_t = c_s + d_{s1}\Delta f_t + d_{s2}(\Delta s_{t-1} - \Delta f_{t-1}) + \zeta_{st} \quad (11)$$

$$\Delta f_t = c_f + d_{f1}\Delta s + d_{f2}(\Delta s_{t-1} - \Delta f_{t-1}) + \zeta_{ft} \quad (12)$$

$$\sigma_{st}^2 = \delta_s + \sum_{i=1}^{p} a_{si}\zeta_{s(t-i)}^2 + \sum_{j=1}^{q} b_{sj}\sigma_{s(t-j)}^2 \quad (13)$$

$$\sigma_{ft}^2 = \delta_f + \sum_{i=1}^{p} a_{fi}\zeta_{f(t-i)}^2 + \sum_{j=1}^{q} b_{fj}\sigma_{f(t-j)}^2 \quad (14)$$

$$\sigma_{sft} = \rho\sqrt{\sigma_{st} \times \sigma_{ft}} \quad (15)$$

Where ρ is the correlation coefficient between two underlying assets, which is assumed to be constant.

When spot and futures markets for CO_2 emissions allowances are mature, the basis risks in spot-futures prices are smaller, then the error correction terms denote basis risks are feasible, and they indicate cointegrated relations in spot-futures prices. However CO_2 emissions allowances markets are of emerging markets, the basis risks are larger, estimated optimal hedge ratios have the bigger bias and affect hedging efficiency by using error correction term induced basis risk. We develop the general modified ECM-GARCH structure.

$$\Delta s_t = c_s + d_s\Delta f_t + \sum_{i=1}^{m} u_{si}\Delta s_{t-i} + \sum_{j=1}^{n} v_{sj}\Delta f_{t-j} + w_s\xi_{t-1} + \varsigma_{st} \quad (16)$$

$$\Delta f_t = c_f + d_f\Delta s_t + \sum_{i=1}^{m} u_{fi}\Delta s_{t-i} + \sum_{j=1}^{n} v_{fi}\Delta f_{t-j} + w_f\xi_{t-1} + \varsigma_{ft} \quad (17)$$

Where the residual terms $(\varsigma_{st}, \varsigma_{ft})^T$ follow BGARCH process, the residual term $\xi_{t-1} = \Delta s_t - (a + b\Delta f_t)$. In the above equation (16-17), the bivariate GARCH may be incorporated into the EC model, we can obtain optimal hedge ratios from the ECM- GARCH and modified ECM –GARCH model. In each case, one-period hedge ratio h^* is equal to $\frac{\sigma_{sf}^2}{\sigma_f^2}$, which is time-varying trend.

4.3 Empirical Results of Dynamic Hedge Ratio

Due to nonlinearity caused by the GARCH effects, the optimally dynamic hedge ratios change with the change of hedging time series. To calculate the dynamic hedge ratio over multiple days, we rely upon iterations from equation (11) to equation (17). A bivariate ECM-GARCH is used to estimating time-varying hedge ratios by the error correction terms. The modified ECM-GARCH is incorporated into the previous price series and the residual term from two-step EG method.

Shown in the following table 3 and 4, except intercept term, z-statistic value of estimated coefficients from the ECM-GARCH(1,1) and modified ECM- GARCH(1,1) model are all larger, their probabilities are all extremely small. Accordingly estimated parameters coefficients are significant at the significant level 99%. Based on estimated coefficients in the table 3 and 4, we can attain the optimally dynamic hedge ratios by the ECM-GARCH (1,1) and modified ECM-GARCH (1,1) methods.

Shown from figure 2 to figure 6, the optimal hedge ratios from ECM-GARCH (1,1) and modified ECM-GARCH(1,1) are all time-varying and their volatilities of optimal hedge ratios are of fierce jump. In the following table 5, we propose statistical description of dynamic hedge ratio from the above two model. As we have seen from the table 5, the means of OHR from the ECM-GARCH(1,1) are larger than those from modified ECM-GARCH(1,1) between spot and futures F_1, F_3, F_4, however means of OHR from ECM- GARCH(1,1) are less than those from modified ECM-GARCH(1,1) between spot and futures F_2, F_5. Standard deviations of hr_1, hr_4 are bigger than them of mhr_1, mhr_4, however standard deviations of hr_2, hr_3, hr_5 are less than them of mhr_2, mhr_3, mhr_5.

Table3 Estimated parameters coefficients from the ECM-GARCH(1,1)

coefficients	F_1	F_2	F_3
δ_s	2.84e-7	7.21e-8	4.78e-8
δ_f	2.53e-7	8.09E-8	6.78e-8
a_{s1}	0.150^{***}	0.101^{***}	0.076^{***}
	(8.06)	(8.66)	(7.63)
a_{f1}	0.143^{***}	0.103^{***}	0.088^{***}
	(8.71)	(8.70)	(8.22)
b_{s1}	0.843^{***}	0.897^{***}	0.923^{***}
	(48.44)	(74.59)	(89.74)
b_{f1}	0.850^{***}	0.895^{***}	0.910
	(48.71)	(73.17)	(82.50)
coefficient	F_4	F_5	
δ_s	4.70e-8	2.18e-7	
δ_f	2.46e-8	1.60e-7	
a_{s1}	0.064^{***}	0.081^{***}	
	(12.24)	(14.66)	
a_{f1}	0.048^{***}	0.069^{***}	
	(17.56)	(13.76)	
b_{s1}	0.935^{***}	0.916^{***}	
	(175.40)	(160.45)	
b_{f1}	0.952^{***}	0.928^{***}	
	(343.11)	(172.67)	

Table 4 Estimated parameter coefficients from the modified ECM-GARCH(1,1)

coefficients	F_1	F_2	F_3
δ_s	1.92e-7	9.20e-8	1.14e-7
δ_f	1.72e-7	1.08e-7	1.48e-7
a_{s1}	0.175^{***}	0.138^{***}	0.121^{***}
	(9.65)	(9.50)	(8.83)
a_{f1}	0.169^{***}	0.148^{***}	0.136^{***}
	(10.01)	(9.27)	(8.80)
b_{s1}	0.818^{***}	0.858^{***}	0.876^{***}
	(41.88)	(55.88)	(60.43)
b_{f1}	0.825^{***}	0.848^{***}	0.859^{***}
	(45.56)	(50.15)	(51.88)
coefficients	F_4	F_5	
δ_s	8.80e-8	4.21e-6	
δ_f	8.43e-8	3.36e-6	
a_{s1}	0.085^{***}	0.485^{***}	
	(13.83)	(15.50)	
a_{f1}	0.077^{***}	0.492^{***}	
	(13.47)	(14.76)	
b_{s1}	0.915^{***}	0.470^{***}	
	(147.16)	(13.05)	
b_{f1}	0.921^{***}	0.453^{***}	
	(155.43)	(12.00)	

*Note: F_1-F_5 denote the EUA futures contracts for emissions allowances with the varying maturity going from December 2009 to December 2014. *** denote significant at the significant level 99%, the number in the parentheses is z-statistic values.*

Table5 Statistical description of optimally time-varying hedge ratio

futures	*mean*	*std.dev*	*maximun*	*minimum*
$F_1(hr_1)$	0.962	0.039	1.125	0.833
$F_1(mhr_1)$	0.961	0.036	1.148	0.835
$F_2(hr_1)$	0.981	0.035	1.122	0.863
$F_2(mhr_1)$	0.983	0.037	1.119	0.878
$F_3(hr_1)$	1.005	0.047	1.142	0.872
$F_3(mhr_1)$	1.002	0.051	1.159	0.856
$F_4(hr_1)$	1.013	0.101	2.306	0.856
$F_4(mhr_1)$	1.008	0.057	1.313	0.842
$F_5(hr_1)$	1.069	0.065	1.479	0.916
$F_5(mhr_1)$	1.108	0.139	1.905	0.755

Note: hr_{1-5}, mhr_{1-5} denote optimally dynamic hedge ratio from ECM-GARCH(1,1) and modified ECM-GARCH(1,1) model between spot and futures contracts with the varying maturity going from December 2009 to December 2014.

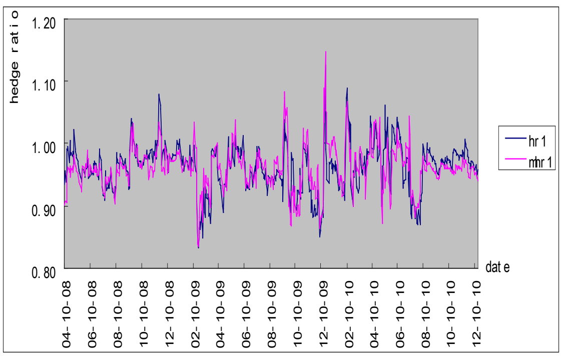

Figure 2: Dynamic hedge ratio between spot and futures F_1

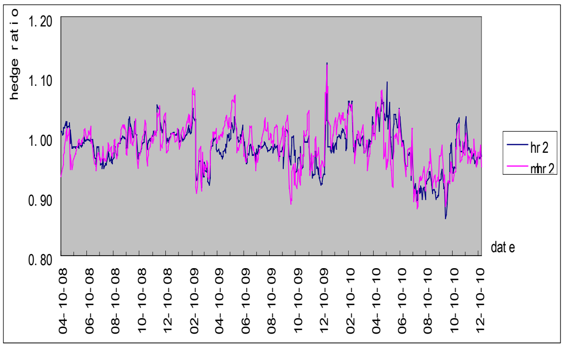

Figure 3: Dynamic hedge ratio between spot and futures F_2

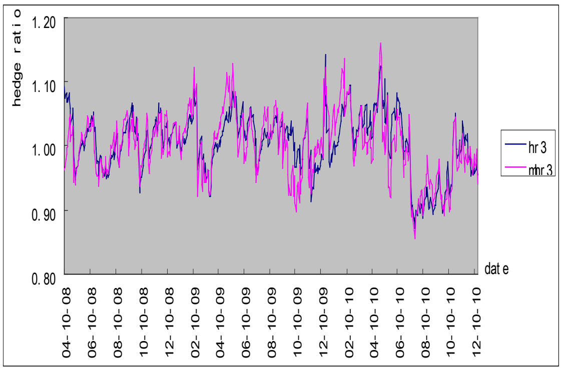

Figure 4: Dynamic hedge ratio between spot and futures F_3

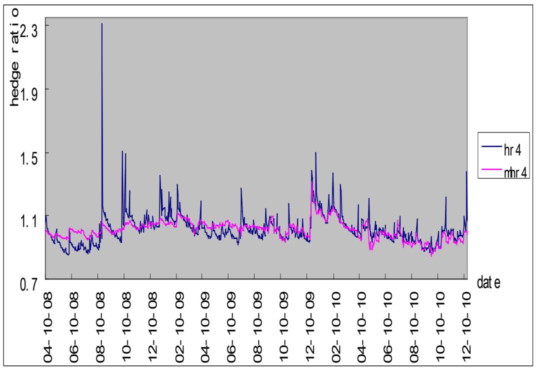

Figure 5: Dynamic hedge ratio between spot and futures F_4

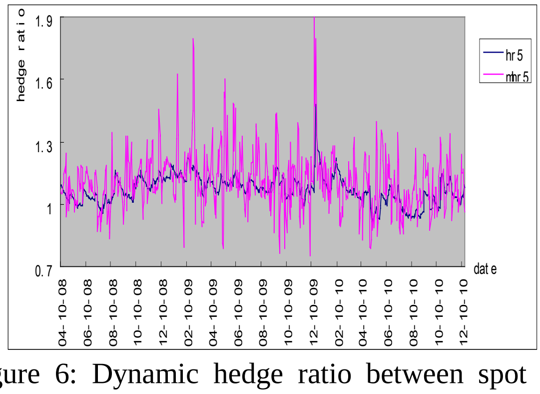

Figure 6: Dynamic hedge ratio between spot and futures F_5

5 Hedging Effectiveness Comparison of Assets Portfolio Returns

5.1 Statistical Description of Time-varying Hedging Portfolio Returns

Neri (2011) simulate the structure of financial market by combining nature computation and agent simulation, and then DJIA time series shows their effectiveness of this approach in modeling financial data[24]. The variance of hedging portfolio returns is a standard measure of risk in many financial markets and has become the dominant measure of hedging effectiveness by market hedgers and investors. Since the evaluation of hedging effectiveness used by Ederington (1979), the minimum variance of hedging portfolio returns has been extensively applied in the literature on hedging in financial markets [25].Seen from the following figure 7 to figure 11, irrespective of transactions costs, the variance of dynamic hedging returns between spot and futures contracts with different maturities going from December 2009(F_1) to December 2014(F_5) are updated every time period. In order to compare with dynamic hedging portfolio (DHP) effectiveness, we propose the returns risk of DHP induced from ECM-GARCH (1,1) and modified ECM-GARCH (1,1) by using the equation (9). Shown in the table 6 and from figure 7 to figure 11, the variance of dynamic hedging portfolio returns has strongly time-varying motion trend between spot and futures contracts with different maturities. Means and standard deviations in the variance of optimal hedging returns from the modified ECM-GARCH (1,1) are less than them in the variance of optimal hedging returns from the ECM-GARCH(1,1) between spot and futures contracts with different maturities. And the efficiency of dynamic hedging portfolio from the modified ECM-GARCH (1,1) is better than the efficiency of DHP from the ECM-GARCH(1,1).

Table 6 Statistical description in the variance of dynamic hedging portfolio returns

variance	mean	Std.dev	max	min
F_1(var(hr$_1$)	2.91e-6	3.09e-6	1.92e-5	1.97e-7
F_1(var(mhr$_1$)	2.11e-6	2.32e-6	1.30e-5	9.93e-8
F_2(var(hr$_1$)	2.01e-6	2.33e-6	1.18e-5	1.01e-7

F_2(var(mhr$_1$)	1.71e-6	2.10e-6	9.37e-6	6.93e-8
F_3(var(hr$_1$)	2.78e-6	2.98e-6	1.35e-5	1.49e-7
F_3(var(mhr$_1$)	2.53e-6	2.87e-6	1.46e-5	1.41e-7
F_4(var(hr$_1$)	1.08e-5	1.39e-5	9.12e-5	3.96e-7
F_4(var(mhr$_1$)	9.67e-6	1.25e-5	6.33e-5	3.47e-7
F_5(var(hr$_1$)	2.48e-5	3.65e-5	2.17e-4	4.78e-7
F_5(var(mhr$_1$)	1.07e-5	2.61e-5	2.88e-4	5.21e-7

Note: var(hr$_{1-5}$),var(mhr$_{1-5}$) denote the variance of dynamic hedge ratio from ECM-GARCH(1,1) and modified ECM-GARCH(1,1) model between spot and futures contracts with the different maturities from December 2009 to December 2014.

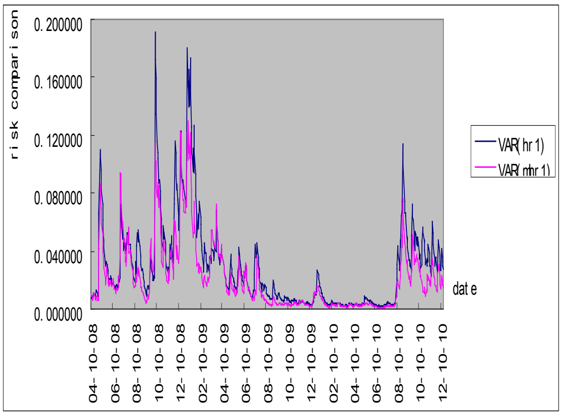

Figure7: Efficiency comparison in dynamic hedging return between spot and futures contract $F_1(\times 10^4)$.

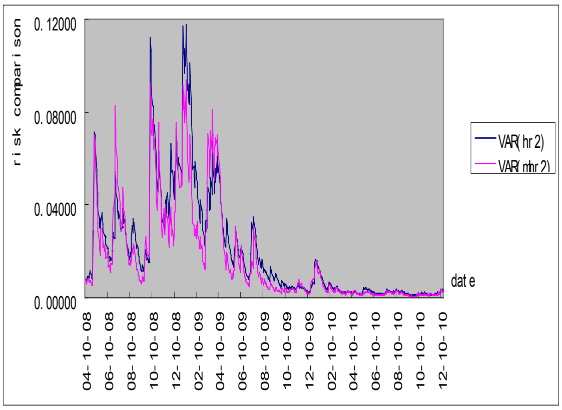

Figure 8:Efficiency comparison in dynamic hedging return between spot and futures contract $F_2(\times 10^4)$.

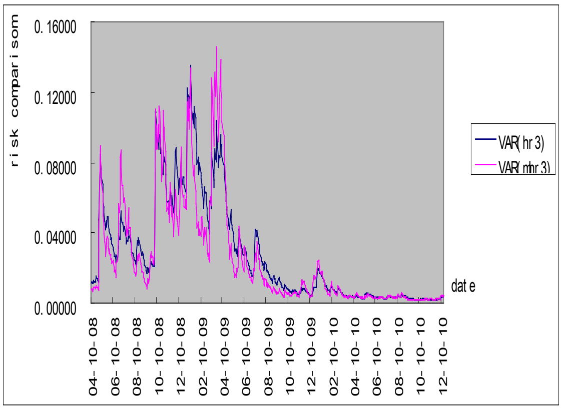

Figure9: Efficiency comparison in dynamic hedging return between spot and futures contract $F_3(\times 10^4)$.

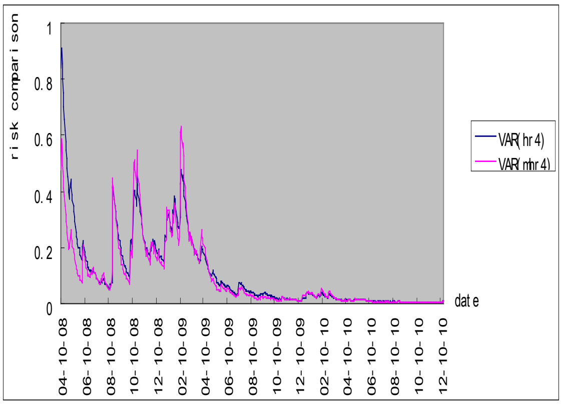

Figure10:Efficiency comparison in dynamic hedging return between spot and futures contract $F_4(\times 10^4)$.

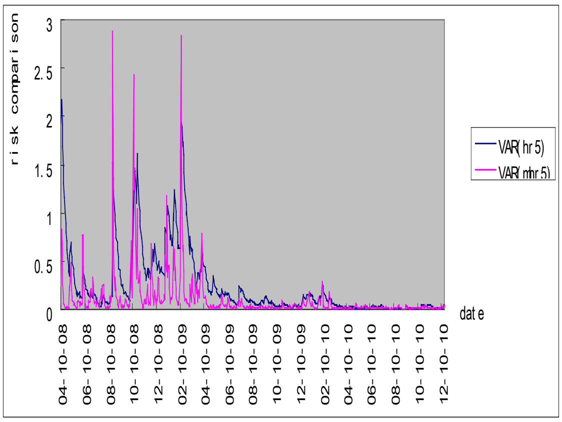

Figure 11: Efficiency comparison in dynamic hedging return between spot and futures contract $F_5(\times 10^4)$.

5.2 Effectiveness Comparison of Hedging Portfolio Returns

Compared with the minimum variance of unhedged portfolio returns, we use the percentage reduction in the variance of hedged portfolio returns evaluate the hedging effectiveness (HE). The hedging portfolio returns are estimated by using the optimal constant and time-varying hedge ratios from two-step EG, ECM, ECM-GARCH and modified ECM-GARCH methods

$$HE = \frac{Var(U_t) - Var(H_t)}{Var(U_t)} \qquad (18)$$

Where $Var(U_t)$ denotes the variance of unhedged portfolio returns, $Var(H_t)$ denotes the variance of optimally hedged portfolio returns. When the futures contracts for CO_2 emissions allowances completely decrease the risks of hedging portfolio returns, we can obtain HE=1 which indicates a 100% reduction in the variance of hedging portfolio returns, whereas we can obtain HE=0 when the hedging portfolio returns donot eliminate risk. The large number of HE shows the better hedging performance between spot and futures contracts with different maturities.

Table 7 Effectiveness comparison of constant and dynamics hedging portfolio returns ($\times 100\%$)

Futures	EG	ECM	ECM-GARCH	Modified ECM-GARCH
F_1	92.297	92.330	99.521	99.653
F_2	93.851	93.855	99.669	99.719
F_3	92.983	92.984	99.543	99.584
F_4	87.603	87.604	98.223	98.410
F_5	87.008	87.009	95.921	98.240

Seen from the table 7, the risk of hedged portfolio returns have higher percentage reduction compared with the risk of unhedged returns. When the hedgers estimate the risk reduction of hedging portfolio returns by using the constant hedge ratios from the two-step EG and ECM model, The hedging effectiveness from the ECM model has slightly better between spot and futures contracts with different maturities. Compared with the hedging effectiveness estimation by using the constant hedge ratios, the hedging effectiveness by the optimally dynamics hedge ratios from the ECM-GARCH and modified ECM-GARCH model has significant higher. Seen from the table 7, we observe the variance of time-varying hedging portfolio returns has approximately 100% reduction, and then the hedgers can attain the higher risk reduction of hedging portfolio returns. The HE from the modified ECM-GARCH model is slightly better than the HE from the ECM-GARCH between spot and futures contracts with different maturities for emissions allowances, and the risk reduction of hedging portfolio returns from the modified ECM-GARCH model is the highest among the hedging portfolio by using four models.

6 Conclusions

Derivatives markets for emissions allowances are of emerging financial markets, several empirical results show spot and futures prices for emissions allowances exhibit time-varying trend and high-jump market behaviours, and accordingly they are higher risk assets. In order to eliminate the risk of assets portfolio returns, we propose constant and time-varying hedge ratios and hedging effectiveness by using two-step EG, ECM, ECM-GARCH and modified ECM-GARCH methods.

The prices series for spot and futures contracts with different maturities exhibit non-stationary trend, while their first different series show stable trend by using ADF tests. Price series between spot and futures contracts with different maturities exhibit significant cointegration relations by using the two-step EG and ECM model. The optimal hedge ratios estimated from the ECM model are all better than OHR from the two-step EG model, and then the error correction and previous prices movement both spot and futures significantly affect the constant hedge ratios.

The optimal hedge ratios exhibit strongly time-varying trend by using the ECM-GARCH and modified ECM-GARCH model, and their volatilities of OHR are of drastic market jump. Means and standard deviations in the variance of optimal hedging returns from the modified ECM-GARCH model are less than them in the variance of optimal hedging returns from the ECM-GARCH model between spot and futures contracts with different maturities.

When the hedgers estimate the risk reduction of hedging portfolio returns by using the constant hedge ratios, the hedging effectiveness from the ECM model has slightly better between spot and futures contracts. The hedging effectiveness by using the dynamics hedge ratios from the ECM-GARCH and modified ECM-GARCH model exhibit significantly better than the HE by constant hedge ratios, and the hedging effectiveness from the modified ECM-GARCH model is the highest among the hedging portfolio returns by using the above four methods.

Our empirical evidences in this paper are helpful to more effectively reduce fluctuations risk of assets portfolio, the investors and hedgers should make optimally time-varying hedging policy to optimize hedging portfolio returns by using dynamic hedge ratio from the modified ECM-GARCH, and then enhance the capabilities in risk reduction of assets portfolio for emissions allowances. Convenience yields for CO_2 emissions allowances is a significant factor to explain prices spreads between spot and futures, and it is very important to captures the risk reduction of assets portfolio. Accordingly future research is to estimate time-varying hedge ratios and hedging effectiveness under the departure of cost-of-carry theory and the stochastic convenience yields, and then compared with the difference of hedging effectiveness.

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