國 立 交 通 大 學

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碩　士　論　文

石油期貨與石油ＥＴＦ價格發現能力之比較

Comparison of price discovery abilities between oil future and oil ETF

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摘 要

本研究使用每五分鐘之日內資料，探討次級房貸前，對於 CL 石油期貨和 USO 石油基金間是否存在共整合關係，並利用向量誤差修正模型分析兩資產間長期均衡與短期變數關係，進而利用訊息比例模型分析並判斷兩資產間之價格發現效率性，並藉由此模型解釋兩市場在價格發現上的主導地位強弱關係。

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ABSTRACT (English)

This study uses five minute intraday-day data and finds the cointegration relationship existed between Light, Sweet Crude Oil futures and United States Oil Fund. Vector error correction model was used to analyze two assets relationship between the long term equipment and short term variable. Information share model was used to analyze and judge that the efficiency of price discovery. This model explains the dominant position relationship between the strong and weak in two markets.

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1. Introduction

The purpose of this thesis is to provide different views of the price discovery process between future market and ETF market. The U.S. real estate market melts down very fast since middle of 2006, after the FED (Federal Reserve System) raised interest rate to worsen the problems of the outbreak of the subprime mortgage. On the end of July, 2007, the subprime mortgage crisis was broken out in the U.S. The crisis quickly spread throughout the world and caused a greatest impact on the international financial market. This paper aims to investigate the price dynamic of oil futures and ETF before the subprime mortgage crisis. And we select the data from April of 2006 to October of 2007.

Currently there are two popular common factor models that are used to investigate the mechanics of price discovery: Hasbrouck (1995)and Gonzalo and Granger (1995). Baillie et al. (2002) show that the information share (IS) and permanent-transitory (PT) models that are directly related and provide similar results if the residuals are uncorrelated between markets.

In chapter 1, the background has been introduced and reviews on information share model in the recent years have been discussed in this chapter.

In chapter 2, the data and environment of United States Oil Fund and Light, Sweet Crude Oil futures will be discussed.

In chapter 3, methodology will be discussed, including the Augmented Dickey-Fuller (Dickey-Fuller, 1979) unit root test, Johansen (1991) cointegraion test, Vector Error Correction Model, information share model.

In chapter 4, empirical results will be discussed, including the meaning of economy. In chapter 5, bring the conclusion of the research.

2. DATA AND ENVIRONMENT

United States Oil Fund (USO) is the first oil ETF in U.S. Although the United States Oil Fund is traded on an exchange and can be sold short like an ETF, it is technically structured as a commodity pool, not mutual fund. The United States Oil Fund is a domestic exchange traded security designed to track the movements of light, sweet crude oil ("West Texas Intermediate"). Crude oil began future trading on the NYMEX in 1983 and is the most heavily traded commodity. Information concerning the United Sates oil fund and Light, Sweet Crude Oil futures (CL) is provided in Table 1. Both contracts are denominated in U.S. dollars.

In this study, I will use the term USO (CL) to refer to United States Oil Fund (Light, Sweet Crude Oil futures). This study employs 5-minute intra-day data obtained from Tick Data Inc. and Trade and Quote 3 (TAQ 3). Especially there is no 5-minute intra-day data in TAQ 3 .Therefore I used MATLAB program transferred intra-day data into 5-minute intra-day data. The CL open outcry trading is conducted from 10:00 AM until 2:30 PM on 2006. On 2007, CL open outcry trading is conducted from 9:00 AM until 2:30 PM. The USO opens at 9:30 a.m. and closes at 4:00 p.m. In order to synchronize the data, we choose the same trading time to analyze. The period April 10, 2006 to October 31, 2007 (21906 observations) are obtained from USO. The period April 10, 2006 to October 31, 2007 (23935 observations) are obtained from CL. We have 15634 observations after the merge of the two data. Similarly, I will use the term CL to refer to Light, Sweet Crude Oil futures. The trading volume of CL is more than USO (34199.7, 83165.9). The trading value of CL is more than USO (1965490, 5607790).

The investment objective of USO is to have the changes in percentage terms of the units' net asset value reflecting the changes in percentage terms of the spot price of CL delivered to Cushing, Oklahoma, as measured by the changes in the price of the futures contract on light, sweet crude oil as traded on the New York Mercantile Exchange that is the near month contract to expire, except when the near month contract is within two weeks of expiration, in which case the futures contract will be the next month contract to expire, less USO's expenses. CL trade 30 consecutive months plus long-dated futures initially listed 36, 48, 60, 72, and 84 months prior to delivery.

Table 1. Contract and Exchange Characteristics

	Contract	
	April 10, 2006-October 31, 2007	April 10, 2006-October 31, 2007
	United States Oil Fund	Light, Sweet Crude Oil futures
Panel A		
Trading Symbol	USO	CL
Exchange	American Stock Exchange (AMEX)	New York Mercantile Exchange (NYMEX)
Data	Trade and Quote (TAQ)	Tick Write 6.0
Location	New York	New York
Traing Hours	9:30 a.m.~4:00 p.m	9:30 a.m.~4:00 p.m
Currency Senomination	U.S. dollars	U.S. dollars
Leverage	NO	YES
Management Expense Ratio	0.45%	NO
Panel B		
Trading Volume ($\times 10^4$)	3.41997	8.31659
Trading Value ($\times 10^6$)	1.96549	5.60779

Note:

Sample size of 15634 observations. Intra-day data with a five-minute interval for CL and USO indices are used. The logarithm of future and ETF prices is not used.

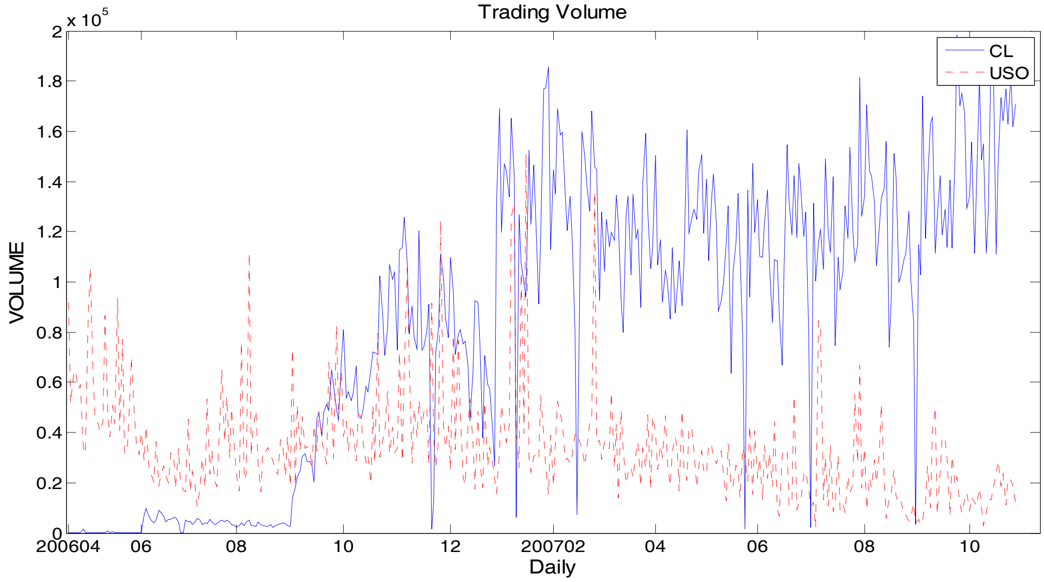

Figure 1. This figure indicates that trading volume. Accumulate each five intraday data of trading volume. We may indicate by a figure what CL trading volume and USO trading volume. The CL trading volume is more than USO.

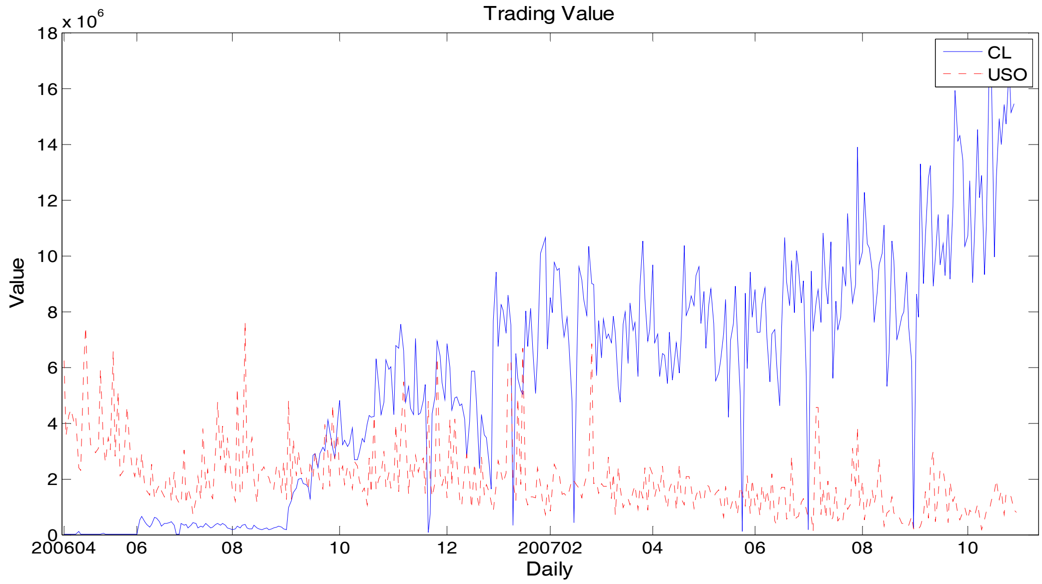

Figure 2. This figure indicates that trading value. Accumulate each five intraday data of trading value. We may indicate by a figure what CL trading value and USO trading value. The CL trading value is more than USO.

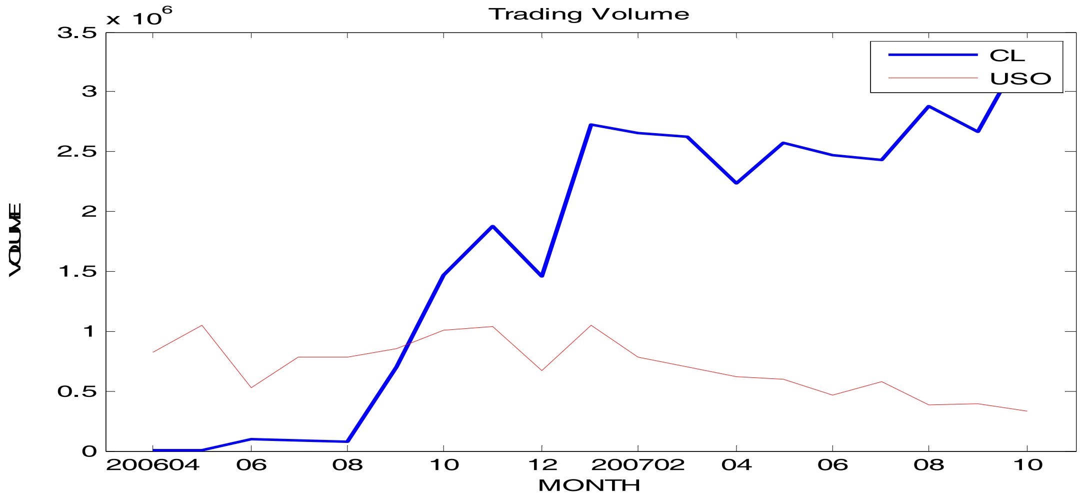

Figure 3. This figure indicates that trading volume. Accumulate each month data of trading volume. The CL trading value is more than USO.

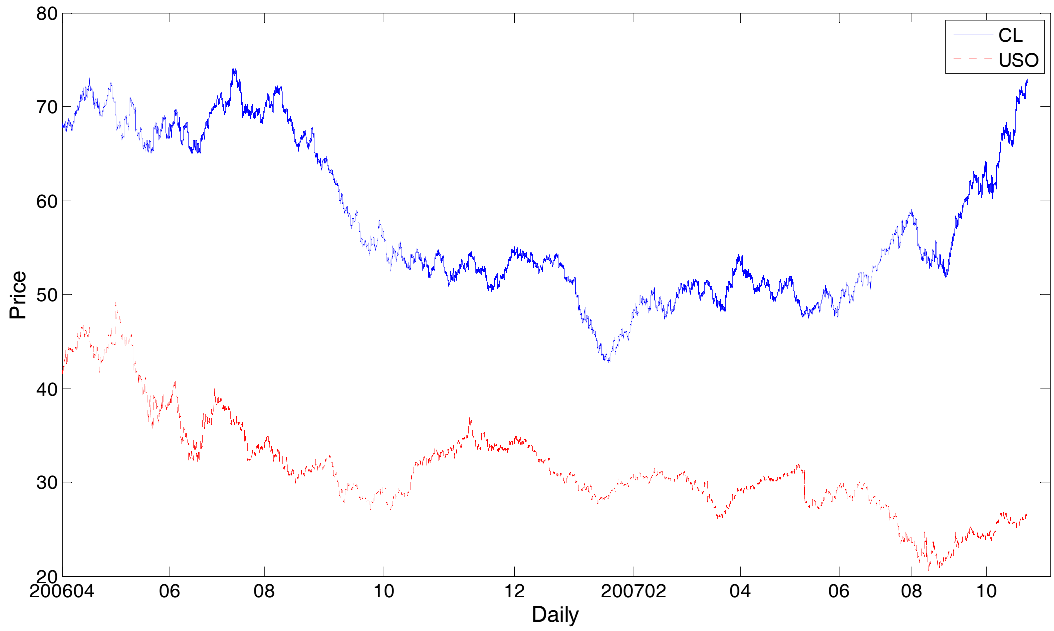

Figure 4. The historical prices of USO and CL.

3. METHODOLOGY

As a beginning, we will examine that the close price of CL and USO follow a I(1) process. This is using the Augmented Dickey-Fuller (Dickey-Fuller, 1979) unit root test. Next, the Johansen (1991) test indicates that the two series are cointegrated. Furthermore, we utilize the Vector Error Correction Model (VECM) to examine the error correction process. Finally, the information share (IS) as defined by Hasbrouck (1995) and used it to analysis price discovery of CL and USO.

3.1 ADF unit root test and Johansen Cointegration Test

The Augmented Dickey-Fuller test is a test for a unit root in a time series sample. Consider a y series follows an AR(P) process and adding p lagged difference terms of the dependent variable y to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + x_t{}'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \ldots + \beta_p \Delta y_{t-p} + v_t \ . \qquad (1)$$

Where x_t are optional exogenous regressors which may consist of constant, or a constant and trend, α and δ are parameters to be estimated, and the v_t will be autocorrelated if there was autocorrelation in the dependent variable of the regression Δy_t .The null hypotheses $H_o : \alpha = 0$ against the one-sided alternative $H_1 : \alpha < 0$. The test t-statistic of $H_o : \alpha = 0$ is also called ADF-t statistic.

$$ADF - t = \hat{\alpha} / \sqrt{\hat{Var}(\hat{\alpha})} \qquad (2)$$

Where $\hat{\alpha}$ is the estimate of α, and $\sqrt{\hat{Var}(\hat{\alpha})}$ is the coefficient standard error.

So, the ADF-t test is a left-tailed test, the smaller ADF-t statistic is, the more can rejected null hypotheses with unit root.

The time series of the economic parameter does not usually belong to the stationary process. There is a common trend between each other. As Granger (1986) acutely pointed out, two or a lot of integration is the same non-stationary series, its perhaps one or more long-term common trends exist. This makes the linear combination between the parameters to a stationary series. If such a stationary linear combination existed, then the non-stationary series are said to be cointegrated. It is means that parameter has long-term steady equilibrium relation.

The CL and USO series are non-stationary before first difference.

3.2 Vector error correction model (VECM)

According to Engle and Graner (1987) Research point out must exist for an error correction term if two parameter X_t and Y_t have cointegrating relationships. Its idea is by previous no long-term cointegration equilibrium, the short-term dynamic phenomenon of revision. Explain several short-run change relations and adjust the balanced course for a long-term form the short-term unbalanced state, can express the relation between the two with vector error correction model:

$$\Delta X_t = \delta_1 + \alpha_1 Z_{t-1} + \sum_{i=1}^{p} \beta_{1x} \Delta X_{t-i} + \sum_{j=1}^{q} \beta_{1y} \Delta Y_{t-j} + \varepsilon_{1t} \quad (3)$$

$$\Delta Y_t = \delta_2 + \alpha_2 Z_{t-1} + \sum_{i=1}^{p} \beta_{2x} \Delta X_{t-i} + \sum_{j=1}^{q} \beta_{2y} \Delta Y_{t-j} + \varepsilon_{2t} \quad (4)$$

where $Z_{t-1} = X_{t-1} - \alpha Y_{t-1}$ is an error correction term; δ_1 and δ_2 are constant terms; α_1 and α_2 are correction coefficient; △ is a difference operator; and

ε_{1t} and ε_{2t} are white noises.

3.3 Information Share

Hasbrouck (1995) uses the concept of information share to analyze the contributions of different markets to this efficient price in terms of the variance of innovations in the common factor. The information share (IS) models start from the estimate of the vector error correction model:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{p} A_j \Delta X_{t-j} + \varepsilon_t \tag{5}$$

α where is an n×1 error correction vectors, β is a 1×n matrix of cointegrating vectors, $X_t = \{x_{it}\}$ is an n×1 vector of cointegrated prices, and ε_t is an n×1 zero-mean vector of serially uncorrelated innovations with covariance matrix Ω.

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix} \tag{6}$$

where σ_1^2 is the variance of ε_{1t}, σ_2^2 is the variance of ε_{2t}, and ρ is the correlation between ε_{1t} and ε_{2t}.The vector error correction model has two parts. The first parts is $\alpha\beta' X_{t-1}$ depicts to equilibrium dynamics between the price series. The second part is $\sum_{i=1}^{p} A_j \Delta X_{t-i}$ represents the short-run dynamics contains market imperfections. Hasbrouck (1995) transforms the VECM in Eq. (1) into an integral from of an n×n vector moving average (VMA):

$$X_t = l\eta(\sum_{q=1}^{t} \varepsilon_q) + \Phi^*(L)\varepsilon_t \tag{7}$$

where l is an n×1 vector of ones, $\eta = (\eta_1, \eta_2 ..., \eta_n)$ is a row vector, Φ* is a matrix of polynomials in the lag operator L. Hasbrouck (1995) defines the information share of market j by

$$S_j = \frac{([\eta M]_j)^2}{\eta \Omega \eta'} \qquad (8)$$

where M is the Cholesky factorization of Ω, M is a lower triangular matrix. If the covariance matrix is not diagonal, the information share is not exactly identified. The results depend on the ordering of variables in the Cholesky factorization of Ω. A Distinct orderings of the variables will cause lower and upper bounds of a market's information share. For detailed discussion of the information share model and alternative procedures see that Baillie et al. (2002), De Jong (2002), Grammig et al. (2005), Harris et al. (2002), Hasbrouck (2002), and Lehmann(2002). To simplicity, see Baillie et al. (2002) information share only depend on alpha and Ω. The figure 5 tells us the research method.

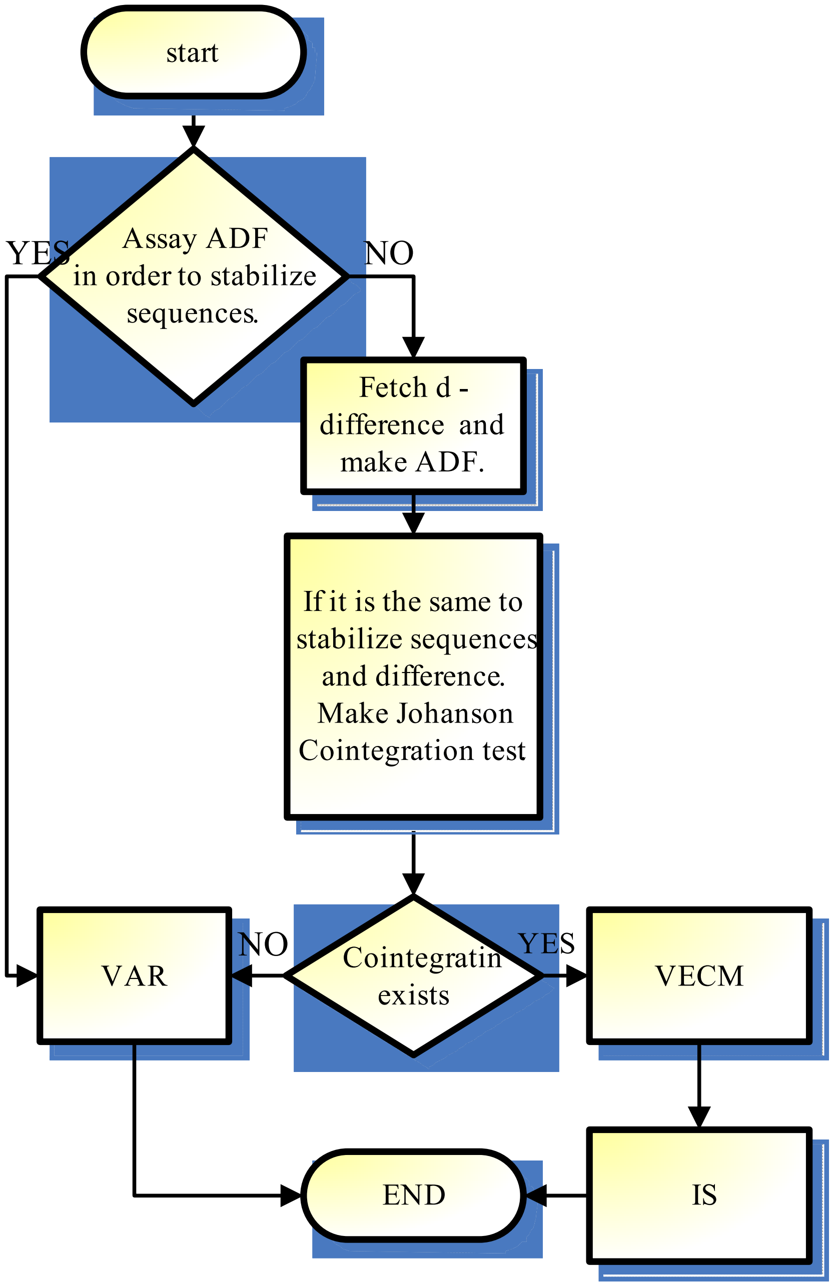

Figure 5. Flow Chart of Research Method

4. EMPIRICAL RESULTS

4.1 Stationary and cointegration tests

Table 2 shows the ADF unit root test, and CL series and USO series are stationary after the first difference. Because p-value less than 0.05 we reject null hypothesis and series are regarded as stationary.

Table 2. ADF Unit Root Test

	CL		USO	
	t-Statistic	Prob.*	t-Statistic	Prob.*
ADF test statistic		0.0001		0.0001
TREND(1)		0.0289		0.0135
Test critical value at the 1% level	-3.4306		-3.4306	
Test critical value at the 5% level	-2.8615		-2.8615	
Test critical value at the 10% level	-2.5668		-2.5668	

Note:
The unit root tests are based on the Augmented Dicket-Fuller (Dickey & Fuller,1979)
*MacKinnon (1996) one-sided p-values.

Table 3 shows at least one cointegrating relationship did exist of CL and USO series under unrestricted cointegration rank tests. When CE(s)=0, if p-value<0.05, then one cointegration equation exist. When CE(s)≦1, if p-value >0.05, then at most one cointegration equation exist. Two series exists at least one cointegrating relationship means that have common stochastic trend. Two series has long-run equilibrium prior to the subprime mortgage crisis.

Table 3. Unrestricted Cointegration Rank Test

Series: **CL and USO**

Hypothesized	Trace test		Maximum eigenvalue test	
No. of CE(s)	Critical Value	Prob.**	Critical Value	Prob.**
CE(s)=0 *	25.8721079	0.03247618	19.38704	0.0255
CE(s)≦1	12.5179829	0.46123161	12.51798	0.4612

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Note:

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

4.2 VECM

Table 6(a)/6(b) shows that the results of the Vector Error Correction Model (VECM) for the CL/USO and USO/CL. Table 6(a) shows that the error correction term (Z_{t-1}) of CL and USO are (-0.00133, 0.002093) in the long-term equilibrium. Table 6(b) reveals that the error correction term (Z_{t-1}) of USO and CL are (-0.00053, -0.00044) in the long-term equilibrium. The coefficient (Z_{t-1}) measures the speed of adjustment of the variable towards the equilibrium. In the long run the speed of response to new information within the USO ETF market is faster than in the CL Future market ($|-0.00133|<0.002093$ & $|-0.00053|>|-0.00044|$). The CL future market is more dominant than USO ETF market. This means that when the price relationship of two indexes deviates from long-run equilibrium, the USO ETF market will adjustment series to reestablish equilibrium.

In the short-term equilibrium, the $\triangle CL_{t-1}$ ($\triangle CL_{t-2}$) is difference CL series and lag five (ten) munities . In the short-term equilibrium, the $\triangle USO_{t-1}$ ($\triangle USO_{t-2}$) is difference USO series and lag five (ten) munities .

Table 6(a) display that if CL is explanatory variable have noticeable effect to $\triangle USO_{t-1}$, $\triangle USO_{t-2}$, $\triangle USO_{t-3}$ (| t-value |>1.96). If USO is explanatory variable have noticeable effect to $\triangle CL_{t-1}$, $\triangle CL_{t-2}$, $\triangle CL_{t-3}$. Table 6(b) display that if USO is explanatory variable have noticeable effect to $\triangle CL_{t-1}$, $\triangle CL_{t-2}$. If CL is explanatory variable have noticeable effect to $\triangle USO_{t-1}$.

We can find that the CL future market is dominant the USO ETF market. It does not influence the dominance relation to change two variables.

Table 4. Vector Error Correction Model (20060410~20071031)

(a)	Series: CL and USO		
	Independent Variables	20060410~20071031 CL	USO
	Z_{t-1}	-0.00133	0.00209
		(0.00172)	(0.00139)
	$\triangle CL_{t-1}$	-0.14803	0.10727
		(0.0167)	(0.01346)
		[-8.86301]*	[7.97050]*
	$\triangle CL_{t-2}$	-0.02914	0.09839
		(0.01724)	(0.0139)
		[-1.68960]	[7.08001]*
	$\triangle CL_{t-3}$	-0.04647	0.03437
		(0.01726)	(0.01391)
		[-2.69202]*	[2.47121]*
	$\triangle CL_{t-4}$	-0.02605	0.00721
		(0.01668)	(0.01344)
		[-1.56188]	[0.53645]
	$\triangle USO_{t-1}$	0.20622	-0.12196
		(0.02071)	(0.01669)
		[9.95591]*	[-7.30691]*
	$\triangle USO_{t-2}$	0.04557	-0.11675
		(0.02143)	(0.01727)
		[2.12675]*	[-6.76146]*
	$\triangle USO_{t-3}$	0.06652	-0.34324
		(0.02141)	(0.01725)
		[3.10661]*	[-1.98929]*
	$\triangle USO_{t-4}$	0.02746	-0.00712
		(0.02072)	(0.0167)
		[1.32525]	[-0.42647]
	C	0.00200	-1.83E-05
		(0.00156)	(0.00118)
		[1.37037]	[-0.01557]

(b) Series: USO and CL

Independent Variables	20060410~20071031 USO	CL
Z_{t-1}	-0.00053	-0.00044
	(0.00019)	(0.00024)
$\triangle USO_{t-1}$	-0.11801	0.19732
	(0.01647)	(0.02044)
	[-7.16495]*	[9.65143]*
$\triangle USO_{t-2}$	-0.10700	0.02643
	(0.0165)	(0.02048)
	[-6.48542]*	[1.29084]
$\triangle CL_{t-1}$	0.10417	-0.14195
	(0.01329)	(0.0165)
	[7.83787]*	[-8.60441]*
$\triangle CL_{t-2}$	0.09021	-0.01425
	(0.01327)	(0.01647)
	[6.79858]*	[-0.86525]
C	4.97 E-05	0.001869
	(0.00117)	(0.00146)
	[0.04234]	[1.28175]

Note: The error correction terms are as follows:

(i) for (a) : $Z_{t-1} = CL_{t-1} - 1.131419\ USO_{t-1} + 8.087517$

(ii) for (b) : $Z_{t-1} = USO_{t-1} - 1.201168\ CL_{t-1} + 22.84801$

(iii) Standard errors in ( )

(iV) t-statistics in []

4.3 Information Share

Panel A of Table 5 shows the covariance matrix of the residuals Ω. Panel B shows the lower triangular matrix M by Cholesky factorization. We receive on the previous section that β=(1 -1.131419) and α=(-0.00133 0.00209)' . And γ=(0.00209 0.00133) by Gonzalo and Granger show that $\alpha_{\perp} = (\gamma_1, \gamma_2)'$. In Panel C of Table 5 we report the IS model information shares. The CL accounts for 0.972042% of the price discovery, much more than USO (0.027958%). That is to say the CL dominant USO markets in price.

Table 5. Price Discovery in Futures(CL) and ETF(USO)

	CL	USO
Panel A: Residual Correlation Matrix, Ω		
CL	0.033193	0.023471
USO	0.023470	0.021553
Panel B: Lower Triangular Matrix, M		
CL	0.182188	0
USO	0.128824	0.070409
Panel C: Information Shares		
	0.972042	0.027958

Notes:
This table reports the results of price discovery using the Hasbrouck (2002) information share model.

Similarly, we change order of two variables to estimate the IS model. Panel A of Table 6 shows the covariance matrix of the residuals Ω. Panel B shows the lower triangular matrix M by Cholesky factorization. We receive on the previous section that β=(1 -1.1201168), α=(-0.00053 -0.00044)’ and

γ=(-0.00044 0.00053). In Panel C of Table 6 we report the IS model information shares. The CL accounts for 0.99999995% of the price discovery, much more than USO (0.00000005%). That is to say the CL dominant USO markets in price.

Table 6. Price Discovery in ETF(USO) and Futures(CL)

	USO	CL
Panel A: Residual Correlation Matrix, Ω		
USO	0.02154691	0.02344009
CL	0.02344009	0.03319741
Panel B: Lower Triangular Matrix, M		
USO	0.12467886	0
CL	0.15968601	0.08773705
Panel C: Information Shares		
	0.00000005	0.99999995

Notes:
This table reports the results of price discovery using the Hasbrouck (2002) information share model.

The same observation applies to both measures show that the CL future market dominate the USO ETF market.

5. Conclusions

This thesis is intended as an investigation of influence before the subprime mortgage crisis. As and empirical application, estimate the IS for the ETF and future markets for USO and CL indices using five minute intra-day data. We find that two series are stationary after the first difference method. Our results exist one cointegrating relationship between the future market and ETF market.

This relationship indicates that exist linear combination between the parameters to a stationary series.

The VECM results show that the CL future market leads the USO ETF market, and that price adjustment occurs mainly in the USO ETF market, thereby resulting in the achievement of long-run price equilibrium. The IS model results show that the CL future market dominate the USO ETF market. Similarly, we change the order of series and the results are the same. The reason CL future market dominates the USO ETF market is because the USO ETF market has management expense and the CL trading volume is more than the USO. This is means that an investor likes to trade the CL future market.

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