

Does Price increases in Chinese Stock Index cause Brent Crude Oil Index? Applying Threshold Cointegration Regression

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Abstract

This paper tests whether price increases in Chinese stock index cause Brent crude oil index. We apply threshold cointegration regression. Our findings in the usual regime suggest that oil price increases do not tend to affect Chinese stock market but oil prices better explain stock returns and stock price increases. However, our findings in the unusual regime suggest that stock price increases can be used as predictors for oil price increases, but oil price increases poorly explain stock price increases. Therefore, our findings could shed lights on threshold cointegrated dynamics of price increases between Brent crude oil and Chinese stock markets.

JEL classification numbers: C32, Q40, G12

Keywords: Threshold cointegration, oil price increase, Chinese stock market, nonlinearity, causality.

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1 Introduction

Many studies have examined the influence of oil prices on the macroeconomics,⁵ stimulated especially by dramatic crude oil price increases because of unstable economic and political situations in the Middle East, but the literature on the relationship between stock market and oil prices is still growing. Understanding the relationship between stock market and oil prices is an important issue. In general, there is negative relationship between oil price and stock markets (Aloui and Jammazi, 2009; Bharn and Nikolovann, 2010; Lee and Chiou, 2011; Filis et al., 2011). Additionally, positive relationships between real stock market prices and the real oil price are revealed (Miller and Ratti, 2009), even though during the 2008 global financial crisis periods (Filis et al., 2011). In contrast, a wealth of literature suggests no relationship between oil price (shocks) and stock markets (Chen et al., 1986; Haung et al., 1996; Cong et al, 2008; Al-Fayoumi, 2009; Ono, 2011). Some studies turns to investigate the dynamics between oil price and stock markets but mixed results are found. Huang et al. (1996) suggest that oil returns do lead some individual oil company stock returns in U.S., but oil future returns do not have much impact on general market indices. Sadorsky (1999) shows that monthly oil price and its volatility both play important roles in affecting monthly real stock returns. Papapetrou (2001) applies a VAR approach and find that oil price changes are important in explaining stock price movement in Greece. Park and Ratti (2008) having examined 13 European countries, they conclude that positive oil price shocks cause positive returns for the Norwegian stock market (oil-exporter), whereas the opposite happens to the rest of the 13 European stock markets (oil-importers). Apergis and Miller (2009), on the other hand, conclude that stock markets (both from oil-importing and oil-exporting countries) tend not to react to oil price shocks (either positive or negative). In additionally, Maghyreh (2004) finds that oil shocks have no significant impact on stock index returns, especially in emerging economies.

Despite many authors early conclude that the nonlinearity of the relation between oil prices and economic activity is responsible for the instability of the empirical relation or misspecification of the functional form,⁶ prior studies usually use VAR model (Huang et al., 1996; Papapetrou, 2001; Maghyreh, 2004; Cong et al., 2008) and cointegrated vector error correction model (VECM) (Miller and Ratti, 2009) to understand the linear relation between stock market and oil prices. Some literatures further examine the nonlinear relation between stock market and oil prices by using GARCH families' models,⁷ but these previous findings fail to account for possible structural breaks, though clearly there is record of structural breaks in crude oil price data, like the increase in the price of crude oil since 2003, its sharp spike at \$142 per barrel in July 2008 and its subsequent collapse in the autumn of 2008. Nevertheless, there is little study on the threshold cointegration and dynamic relation between these two markets. Huang et al. (2005) employ one-regime and

⁵Hamilton (1983) first analyzed the influence of the oil price increase on the U.S. output. The fact that oil affects macroeconomic variables has been examined successively in the studies of Hamilton (1988a, b; 1996; 2009a, b) and Hamilton and Herrera (2004).

⁶Hooker (1996) argues that since the mid-1980s, the linear relation between oil prices and economic activity appears to be either unstable or misspecified.

⁷Prior studies use bivariate EGARCH model (Bharn and Nikolovann, 2010), univariate regime-switching EGARCH model (Aloui and Jammazi, 2009), univariate regime switching GARCH model (Lee and Chiou, 2011), and dynamic conditional correlation asymmetric GARCH (or DCCGARCH-GJR) (Filis et al., 2011), etc.

two-regime multivariate threshold autoregressive models proposed by Hansen and Seo (2002) for the analysis of the US, Canada and Japan. They show that oil price changes better explain stock returns in Canada when the change is above the threshold levels.

Brent oil index is the leading global price benchmark for Atlantic basin crude oils. It is used to price two thirds of the world's internationally traded crude oil supplies (Maghyereh, 2004). In addition, China and the United States are the two largest importers of oil. The Energy Information Administration (EIA) reported that, in 2007, China imported 3.2 million barrels per day, and its estimated usage was around 7 million b/d total. The total amount of oil consumed in China reached 366 million tons in 2007. Hamilton (2009b) argues that demand-side shock deriving from industrialization of countries such as China could have a significant impact in oil price. As of 2012, China has the world's second-largest economy in terms of nominal GDP, totalling approximately US\$7.298 trillion according to the International Monetary Fund (IMF). However, are there factors other than supply and demand now impacting the oil price if China's economic growth moderates?⁸ In this paper, we examine the relations between Brent crude oil price increases and Chinese stock market because most of the related research has focused on stock markets in developed countries, such as the US, UK and so on.

In this study, threshold cointegration model has been applied to test for two-regime threshold cointegration of Brent oil price changes (increases) and Chinese stock market index price changes (increases). This approach allows for non-linear adjustment to the long-run equilibrium and it considers a vector error-correction model (VECM) with one cointegrating vector and a threshold effect based on the error-correction term.⁹ Two regimes are implied by the model and divided into the usual and unusual regime. Given the evidence of stronger linkages between crude oil prices and stock markets in developed economies, this study considers this issue in China. If oil plays a prominent role in an economy, one would expect changes in oil prices affecting changes in stock market index prices as well as oil price increases affecting stock market index price increases in the usually regime. Specifically, it can be argued that China is the world's biggest consumer for oil and China's economic growth moderates, suggesting that oil price increases will not expect to affect stock market index price increases in the unusually regime. In contrary, our findings in the unusually regime will expect stock market index price increases, one factor other than supply and demand, now impacts the oil price increases. It means the evidence of unidirectional causality from stock market index price increases to crude oil price increases.

Our findings in the usual regime suggest that oil price increases do not tend to affect Chinese stock market index price increases but oil price changes better explain stock index

⁸Since economic liberalization began in 1978, China's investment- and export-led economy has grown almost a hundredfold and is the fastest-growing major economy in the world. According to the IMF, China's annual average GDP growth between 2001 and 2010 was 10.5%. Between 2007 and 2011, China's economic growth rate was equivalent to all of the G7 countries' growth combined.

⁹This approach is adopted in several recent papers, revealing threshold-type non-linearities in time series of macroeconomic, for instance, in real exchange rates (Michael et al.; 1997; O'Connell, 1998; Aslanidis and Kouretas, 2005; Nakagawa, 2010), in the term structure (Hansen and Seo, 2002), in purchasing power parity doctrine and the law of one price (Enders and Falk, 1998; Baum et al., 2001; Lo and Zivot, 2001), in covered interest parity (Balke and Wohar, 1998) as well as in modeling interest rate policy (Baum and Karasulu, 1998).

returns and stock index price increases. However, our findings in the unusual regime suggest that stock index price increases can be used as predictors for oil price increases, but oil return and oil price increases poorly explain stock index returns and stock index price increases. Regardless of the existence of threshold cointegration, the evidence of stronger linkages between crude oil prices and stock markets is found in China. Therefore, our results highlight the critical importance of using TVECM in empirical studies on threshold cointegration and dynamics of crude oil price increases and Chinese stock market index price increases. Besides, our findings could shed valuable lights on financial implications of threshold cointegration and the dynamics of crude oil price increases and Chinese stock market index price increases.

The organization of the rest of the paper is as follows. The next section reviews methods developed by Hansen and Seo (2002) and explains the data used, and section 3 summarizes the estimated results. Finally, section 4 concludes the article.

2 Methodology and Data

2.1 VECM methodology

In order to explore effects of possible cointegration, a VAR in error correction form (Vector Error Correction Model, VECM) is estimated using the methodology developed by Engle and Granger (1987) and expanded by Johansen (1988) and Johansen and Juselius (1990). Let $x_t = (IX, CL)$ be a 2-dimensional vector of time series of Chinese stock market index price increases (changes) (*IX*) and the Brent crude oil price increases (changes) (*CL*) respectively with t observations. It is assumed that there exists a long-run relationship between these two time series with a cointegrating vector $\beta = (\beta_0, \beta_1)'$. The bi-variate VECM model has the following form:

$$\Delta x_t = A' X_{t-1}(\beta) + u_t \quad (1)$$

where $X_{t-1}(\beta) = (1, w_{t-1}(\beta), \Delta x_{t-1}, \Delta x_{t-2}, \dots, \Delta x_{t-l})'$, $w_t(\beta)$ denotes the $I(0)$ error-correction term, $X_{t-1}(\beta)$ is $k \times 1$ regressor, and A is $k \times 2$ where $k = 2l + 2$ and l is selected based on SIC. In particular, the estimated coefficients of w_{t-1} denote the different adjustment speeds of the series towards equilibrium.

The X matrix contains parameters for cointegrating vectors of β (CIVs) or long-run stationary equilibria which imply the presence of non-stationary, while the X matrix contains error correction coefficients of $w_t(\beta)$ which measure the extent to which each time series responds to deviations from the long-run equilibria. The test for cointegration is the rank test for r non-zero eigenvalues (λ_i). The test statistic for the null hypothesis of at most r CIVs against the alternative of p CIVs is the λ_{trace} statistic given in (2):

$$\lambda_{\text{trace}} = -T \sum_{i=r+1}^p \ln(1 - \lambda_i) \quad (2)$$

On the other hand, the test statistic for the null hypothesis of r against the alternative of $r + 1$ CIVs is the λ_{max} statistic given in (3):

$$\lambda_{\text{max}} = -T \ln(1 - \lambda_{r+1}) \quad (3)$$

where the critical values for λ_{trace} and λ_{max} statistics are obtained from MacKinnon, Haug, and Michelis (1999).

2.2 TVECM Methodology

Estimation of the threshold parameters

As continued above assumption for 2-dimensional vector of time series of x_t and cointegrating vector of β , we follow Hansen and Seo (2002) to model a threshold vector error correction model (TVECM) of order $l + 1$ of Chinese stock market index price increases (changes) (IX) and the Brent crude oil price increases (changes) (CL). As a motivation for our multivariate nonlinear modeling, Hansen and Seo (2002) examine a two-regime vector error correction model with a single cointegrating vector and a threshold effect in the error-correction term. The two regime threshold model where the γ is the threshold parameter takes the following form,

$$\Delta x_t = \begin{cases} A'_1 X_{t-1}(\beta) + u_t & \text{if } \omega_{t-1}(\beta) \leq \gamma \\ A'_2 X_{t-1}(\beta) + u_t & \text{if } \omega_{t-1}(\beta) > \gamma \end{cases} \quad (4)$$

where $X_{t-1}(\beta) = (1, w_{t-1}(\beta), \Delta x_{t-1}, \Delta x_{t-2}, \dots, \Delta x_{t-l})'$, $w_t(\beta)$ denotes the $I(0)$ error-correction term, the γ is the threshold parameter, $X_{t-1}(\beta)$ is $k \times 1$ regressor, and A is $k \times 2$ where $k = 2l + 2$ and l is selected based on SIC. In particular, the estimated coefficients of w_{t-1} of each regime denote the different adjustment speeds of the series towards equilibrium. This may be rewritten as

$$\Delta x_t = A'_1 X_{t-1}(\beta) \cdot d_{1t}(\beta, \gamma) + A'_2 X_{t-1}(\beta) \cdot d_{2t}(\beta, \gamma) + u_t \quad (5)$$

where $d_{1t}(\beta, \gamma) = 1(\omega_{t-1}(\beta) \leq \gamma)$ and $d_{2t}(\beta, \gamma) = 1(\omega_{t-1}(\beta) > \gamma)$, and $1(\cdot)$ denotes the indicator function.

As described in Hansen and Seo (2002), threshold model (5) has two regimes, defined by the value of the error-correction term. The coefficient matrices A_1 and A_2 govern the dynamics in these regimes. Model (5) allows all coefficients (except the cointegrating vector β) to switch between these two regimes. In many cases, it may make sense to impose greater parsimony on the model, by only allowing some coefficients to switch between regimes. This is a special case of (5) where constraints are placed on (A_1, A_2) . For example, a model of particular interest only lets the coefficients on the constant and the error correction w_{t-1} to switch, constraining the coefficients on the lagged Δx_{t-j} to be constant across regimes.

The threshold effect only has content if $0 < P(\omega_{t-1} \leq \gamma) < 1$, otherwise the model simplifies to linear cointegration. We impose this constraint by assuming that $\pi_0 \leq P(\omega_{t-1} \leq \gamma) \leq 1 - \pi_0$ where π_0 is a trimming parameter. For the empirical application, we set $\pi_0 = 0.05$.

Hansen and Seo (2002) propose estimation of model (5) by maximum likelihood, under the assumption that the errors u_t are iid Gaussian. The Gaussian likelihood is

$$\ln(A_1, A_2, \Sigma, \beta, \gamma) = -\frac{n}{2} \log |\Sigma| - \frac{1}{2} \sum_{t=1}^n u_t(A_1, A_2, \beta, \gamma)' \Sigma^{-1} u_t(A_1, A_2, \beta, \gamma) \quad (6)$$

where $u_t(A_1, A_2, \beta, \gamma) = \Delta x_t - A'_1 X_{t-1}(\beta) \cdot d_{1t}(\beta, \gamma) - A'_2 X_{t-1}(\beta) \cdot d_{2t}(\beta, \gamma)$.

The MLE $(\hat{A}_1, \hat{A}_2, \hat{\Sigma}, \hat{\beta}, \hat{\gamma})$ are the values which maximize $\ln(A_1, A_2, \Sigma, \beta, \gamma)$. It is computationally convenient to first concentrate out (A_1, A_2, Σ) . That is, hold (β, γ) fixed and compute the constrained MLE for (A_1, A_2, Σ) . Additionally, $\hat{A}_1(\beta, \gamma)$ and $\hat{A}_2(\beta, \gamma)$ are the OLS regressions of Δx_t on $X_{t-1}(\beta)$ for the subsamples for which $\omega_{t-1} \leq \gamma$ and $\omega_{t-1} > \gamma$, respectively.

This yields the concentrated likelihood function as follows,

$$\ln(\beta, \gamma) = \ln(\hat{A}_1(\beta, \gamma), \hat{A}_2(\beta, \gamma), \hat{\Sigma}(\beta, \gamma), \beta, \gamma) = -\frac{n}{2} \log |\hat{\Sigma}(\beta, \gamma)| - \frac{np}{2} \quad (7)$$

The MLE $(\hat{\beta}, \hat{\gamma})$ are thus found as the minimizers of $\log |\hat{\Sigma}(\beta, \gamma)|$ subject to the normalization imposed on β as discussed in the previous section and the constraint $\pi_0 \leq n^{-1} \sum_{t=1}^n I(X_t' \beta \leq \gamma) \leq 1 - \pi_0$. This criterion function (7) is not smooth, so conventional gradient hill-climbing algorithms are not suitable for its maximization. In the leading case $p=2$, we suggest using a grid search over the two-dimensional space (β, γ) . In higher dimensional cases, grid search becomes less attractive, and alternative search methods might be more appropriate. Note that in the event that β is known a priori, this grid search is greatly simplified. To execute a grid search, one needs to pick a region over the threshold parameter (γ) and cointegrating vector (β) to joint grid search.

Tests for threshold effects

A test for the null of no cointegration in the context of the threshold cointegration model is conducted. Pippenger and Goering (2000) present simulation evidence that linear cointegration tests can have low power to detect threshold cointegration. This testing problem is quite complicated, as the null hypothesis implies that the threshold variable (the cointegrating error) is non-stationary, rendering current distribution theory inapplicable. To overcome this testing problem, the LM statistic with testing for the presence of the threshold cointegration is employed as follow.

$$\begin{aligned} LM(\beta, \gamma) = & \text{vec} \left(\hat{A}_1(\beta, \gamma) - \hat{A}_2(\beta, \gamma) \right)' \times \left(\hat{V}_1(\beta, \gamma) + \hat{V}_2(\beta, \gamma) \right)^{-1} \\ & \times \text{vec} \left(\hat{A}_1(\beta, \gamma) - \hat{A}_2(\beta, \gamma) \right) \end{aligned} \quad (8)$$

Additionally, Hansen and Seo (2002) developed two tests the SupLM^0 and the SupLM tests for a given or estimated β using a parametric bootstrap method to calculate asymptotic critical values with the respective p-values. The first test is denoted as:

$\text{supLM}^0 = \sup_{\gamma_L \leq \gamma \leq \gamma_U} LM(\beta_0, \gamma)$ and would be used when the true cointegrating vector β is known a priori.

The second test is used when the true cointegrating vector β is unknown and they denote this test statistic as $\text{supLM} = \sup_{\gamma_L \leq \gamma \leq \gamma_U} LM(\hat{\beta}, \gamma)$ where $\hat{\beta}$ is the null estimate of the

cointegrating vector. In these tests, the search region $[\gamma_L, \gamma_U]$ is set so that γ_L is the π_0 percentile of \tilde{w}_{t-1} [where: $\tilde{w}_{t-1} = w_{t-1}(\hat{\beta})$], and γ_U is the $(1-\pi_0)$ percentile.

Finally, the asymptotic distribution depends on the covariance structure of the data, precluding tabulation. Hansen and Seo (2002) suggest using either the fixed regressor bootstrap of Hansen (1996, 2000), or alternatively a parametric residual bootstrap algorithm,

to approximate the sampling distribution where the tests were done using a parametric bootstrap method with 1000 replications.

2.3 Granger Causality Test on VECM and TVECM

To conduct Granger causality test for short- and long-run dynamics of Chinese stock index price increases (changes) (IX) and the Brent crude oil index price increases (changes) (CL) in the VECM and TVECM respectively, the VECM is written as follow;

$$\begin{aligned}\Delta IX_t &= \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t} \\ \Delta CL_t &= \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t}\end{aligned}\quad (9)$$

On the other hand, threshold model with two regimes (4) is rewritten as follow.

$$\begin{aligned}\Delta IX_t &= \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t} \\ \Delta CL_t &= \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t}\end{aligned}, \omega_{t-1} \leq \gamma \quad (10a)$$

$$\begin{aligned}\Delta IX_t &= \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t} \\ \Delta CL_t &= \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t}\end{aligned}, \omega_{t-1} > \gamma \quad (10b)$$

where $\omega_{t-1} = IX_{t-1} - \alpha - \beta \times CL_{t-1}$.

Formally, in the VECM and TVECM model, for short run dynamics of IX and CL , a time series IX causing another time series CL in the Granger sense (denoted as $IX \rightarrow CL$) is that even with information about past values of CL , one can improve the prediction of CL using past values of IX . If the reverse is true, then we say CL Granger-causes IX (or $CL \rightarrow IX$). When both relationships are true, a feedback effect is said to exist between IX and CL .

In addition to indicating the direction of causality among variables, the VECM or TVECM approach allows us to distinguish between 'short-run' and 'long-run' Granger causality. When the variables are co-integrated, in the short-term, deviations from this long-run equilibrium will feed back on the changes in the dependent variable in order to force the movement towards the long-run equilibrium. If the dependent variable is driven directly by this long-run equilibrium error, then it is responding to this feedback. Otherwise, it is responding only to short-term shocks to the stochastic environment. The F-tests of the 'differenced' explanatory variables give us an indication of the 'short-term' causal effects, whereas the 'long-run' causal relationship is implied through the significance. Otherwise, the t test(s) of the lagged error-correction term(s) (ECT) is derived from the long-run co-integrating relationship(s).

2.4 Data and Variables defined

The Shanghai Stock Exchange (SSE) is the world's 5th largest stock market by market capitalization at US\$2.3 trillion as of Dec 2011. There are two types of stocks being issued in the Shanghai Stock Exchange: "A" shares and "B" shares. A shares are priced in the local RMB currency, while B shares are quoted in U.S. dollars. Initially, trading in A shares are restricted to domestic investors only while B shares are available to both domestic (since 2001) and foreign investors. By the end of 2009, China had 870 listed companies and 1,351 listed securities on the SSE where there were 860 A Shares and 54 B Shares. The total

market capitalization of tradable shares was US\$2,841 billion. This study uses the SSE A share index as its benchmark of the performance of the Shanghai Exchange because it reflects the total market capitalization of all listed stocks. This index was launched on February 21, 1992.

On the other hand, the Brent crude oil market is the largest commodity market in the world. Specifically, the Brent crude oil index is used as it accounts for the 60% of the world oil daily production (Maghyereh 2004). The Brent Index is the cash settlement price for the Intercontinental Exchange (ICE) Brent Future based on ICE Futures Brent index at expiry. The index represents the average price of trading in the 21 day Brent Blend, Forties, Oseberg, Ekofisk (BFOE) market in the relevant delivery month as reported and confirmed by the industry media. Only published cargo size (600,000 barrels) trades and assessments are taken into consideration. Thus, this study use Brent crude oil index because it is the leading global price benchmark for Atlantic basin crude oils.

In this study, we use monthly data for Brent crude oil prices and Shanghai A stock market index prices from January 2000 through July 2012. Shanghai A stock index is obtained from Taiwan Economic Journal (TEJ) database while Brent crude oil price is obtained from Datastream database. So the time series of 150 sampling points are obtained.

In this paper, we follow Hamilton (1996) and crude oil price increase is designed to capture how unsettling an increase in the price of crude oil is likely to be for the spending decisions of consumers and firms. If the current price of crude oil is higher than it has been in the recent past, then a positive crude oil price shock has occurred. Crude oil price increase (CLP_INC) is defined as:

$$CLP_INC_t = \max(0, \log CLP_t - \max(\log CLP_{t-1}, \dots, \log CLP_{t-6})), \quad (11)$$

where $\log CLP_t$ is the log of level of Brent crude oil price at time t . Similarly, stock market index price increase (IXP_INC) is defined as:

$$IXP_INC_t = \max(0, \log IXP_t - \max(\log IXP_{t-1}, \dots, \log IXP_{t-6})), \quad (12)$$

where $\log IXP_t$ is the log of level of SSE A share index price at time t . Additionally, IXR and CLR are the monthly return computed as the logarithm price difference for SSE A share index and Brent crude oil index, respectively.

3 Results

3.1 Variability in Stock Index Price and Crude Oil Price

Figure 1 shows plots of price level, price change, and price increases in Shanghai A stock index and Brent crude oil index. For the top of plots, there are records of structural breaks in Shanghai A stock index and Brent crude oil price data clearly, respectively. Shanghai A stock index prices were fairly constant up to the early 2006 after which time they exhibit an upward trend, reaching an all-time high of 6,124.04 points on October 16, 2007. Then, Shanghai A stock index prices ended 2008 down a record 65% mainly due to the impact of the global economic crisis which started in mid-2008.

On the other hand, Brent crude oil prices were fairly constant up to the early 2003 except for a brief correction from mid 2006 peaks near \$75/Bbl to about \$55/Bbl. By mid 2008,

monthly average peaks rose to about \$133/Bbl, with daily peaks approaching \$150/Bbl. Our findings imply structural breaks in Shanghai A stock and Brent crude oil markets, consistent with Lee (2010).



Figure1: Plots of price level (IXP and CLP) and price change (IXR and CLR) as well as price increases (IXP_INC and CLP_INC) in stock index and crude oil index

As shown in middle parts of figure, we present price changes in the nature logarithm of the Shanghai A stock index and Brent crude oil prices over time. Primarily, we observe that stock markets do not always move at the same directions with oil prices. When we observe another period of oil price increases (reaching a peak in late 2000), stock market prices showed an increase, as well. Stock market showed a decreasing pattern during the period 2000–2003.

For the first half of this period, oil prices suffered a decrease, as well. However, for the second half of the 2000–2003 period oil prices were increasing constantly. In addition, the period 2004 until mid-2006 is characterized mainly by a continuous oil price increase, as well as, increased stock market prices. During mid-2006 until early 2007, when an oil price trough is observed, stock markets also exhibited a decrease in their price levels. Moreover, during 2007 until mid-2008 and during early 2009 until September 2009, both oil prices and stock market are bullish. Finally, during the period mid-2008 and early 2009, both oil

and stock market prices experienced a bearish performance. The visual inspection of the middle parts of figures does not provide a clear distinction between stock market performance and oil prices.

As presented in the bottom of figure, we compare the price of Shanghai A stock index and Brent crude oil each month with the maximum value observed during the preceding six months respectively. If the value for the current month exceeds the previous six month's maximum, the percentage change over the previous six month's maximum is plotted. If the price of oil in month t is lower than it had been at some point during the previous six months, the series is defined to be zero for date t . We observe more numbers of price increases in Brent crude oil market than in Shanghai A stock market. Specifically, during 2006 until 2007 mid-2008 Shanghai A stock index price increases reach high of near 0.25 while during 2009 Brent crude oil price increases also reach high of about 0.25. The visual inspection of the bottom of Figures seems to provide a clear distinction between stock market performance and oil prices.

3.2 Summary Statistics

Table 1 reports summary statistics on price level, price change, and price increases on stock index (IX) and crude oil (CL), with mean, median, maximum, minimum, standard deviation, ADF.

From this Table, price change in natural logarithm of stock index (IXR) presents the mean of 0.24% per month and the median of 0.78% as well as the standard deviation of 8.20%, ranging from -28.24% to 24.38% while the mean (median) for price change in natural logarithm of crude oil (CLR) presents price changes of 0.84% per month (2.89% per month), ranging from -44.15% to 32.76%. CLR presents the standard deviation of 11.34%.

Average values for IXP_INC and CLP_INC are 1.62% per month and 2.19% per month respectively, with the maximum of 24.38% for IXP_INC and 25.89% for CLP_INC. Additionally, ADF test for both IX (IXP) and CL (CLP) in level are unit root but stationary for both IXR and CLR as well as IXP_INC and CLP_INC.

Table 1: Summary statistics

Statistics	IX	CL	IXP	CLP	IXR	CLR	IXP_INC	CLP_INC
Mean	2329.0230	59.9163	7.6756	3.9438	0.0024	0.0084	0.0162	0.0219
Median	2074.1050	57.9050	7.6373	4.0588	0.0078	0.0289	0.0000	0.0000
Maximum	6251.5300	138.0500	8.7406	4.9276	0.2438	0.3276	0.2438	0.2589
Minimum	1113.2900	18.3400	7.0151	2.9091	-0.2824	-0.4415	0.0000	0.0000
Std. Dev.	1000.6210	31.9224	0.3841	0.5594	0.0820	0.1134	0.0390	0.0401
Skewness	1.4979	0.5679	0.4923	-0.0536	-0.5361	-0.7209	3.1494	2.4421
Kurtosis	5.5601	2.2035	2.7528	1.7056	4.4262	4.7105	14.0634	10.9998
ADF [†]	-0.7606	-0.2821	0.2862	0.7154	-6.6537**	-	-3.5259*	-5.6301**
						12.0904**		

Note: ** is at 1% significant level; * is at 5% significant level; [†] we conduct ADF test with no intercept.

3.3 Cointegration Test

Table 2 presents the results from Johansen cointegration tests for the VECM. With the optimal lag of $l = 5$ selected based on SIC, the λ_{trace} and λ_{max} statistics consistently indicate one CIV for price levels in stock index and crude oil as well as for price increases in stock index and crude oil at the 5% level respectively.

However, many authors early conclude that the nonlinearity of the relation between oil prices and economic activity is responsible for the instability of the empirical relation or misspecification of the functional form. Hence, existed cointegration literatures may fail to account for possible structural breaks as shown in Figure 1. We would conduct the threshold cointegration test for price levels in stock index and crude oil as well as for price increases in stock index and crude oil respectively.

Table 2: Cointegration test

Panel A: Cointegration test for price levels in stock index and crude oil

	No. of CIV(s)	Eigenvalue	Statistic	Critical Value	Prob.
Trace	None	0.0774	11.6661	12.3209	0.0642
	At most 1	0.0005	0.0709	4.1299	0.8271
Max-Eigen	None	0.0774	11.5953	11.2248	0.0430
	At most 1	0.0005	0.0709	4.1299	0.8271

Panel B: Cointegration test for price increases in stock index and crude oil

	No. of CIV(s)	Eigenvalue	Statistic	Critical Value	Prob.
Trace	None	0.0899	16.9262	12.3209	0.0079
	At most 1	0.0255	3.6407	4.1299	0.0669
Max-Eigen	None	0.0899	13.2855	11.2248	0.0214
	At most 1	0.0255	3.6407	4.1299	0.0669

Notes: Rejection of the hypothesis at the 0.05 level. MacKinnon-Haug-Michelis (1999) p-values are computed.

3.4 Threshold Cointegration Test

We examine threshold cointegration and dynamics of Shanghai A stock market and Brent crude oil price increase. We will conduct threshold cointegration test of price level in Shanghai A stock index and crude oil as well as price increases in Shanghai A stock index and crude oil, respectively. In other words, we test for two-regime threshold cointegration of IXP and CLP as well as IXP_INC and CLP_INC respectively.

The presence of a threshold was estimated via the application of the Hansen and Seo (2002) SupLM test (when β is estimated). The tests were done using a parametric bootstrap method with 1000 replications, whereas to select the lag length of the VAR we use the Schwartz Information Criterion (SIC), which is minimum at $l=5$. The results of the threshold cointegration test are reported in Table 2. We report the result for the estimated cointegrating vector scenario. For two-regime threshold cointegration test of price level in

stock index and crude oil (IXP and CLP), the LM statistic of 32.6343 is insignificant, suggesting the nonexistence of the threshold cointegration.

Table3: Threshold cointegration test for price level in index and crude oil as well as price increases in index and crude oil

Threshold test	price level in index and oil (IXP, CLP)	price increase in index and oil (IXP_INC, CLP_INC)
Test statistic value	32.6343	45.3344
Fixed regressor C.V.	38.2549	38.1682
(p-value)	(0.3350)	(0.0000)
Residual bootstrap C.V.	37.3763	36.3491
(p-value)	(0.1570)	(0.0000)
Threshold estimate	5.6496	0.0396
Cointegrating vector estimate	0.5675	2.9157
Wald Test for Equality of ECM Coef. (p-value)	4.8694 (0.0876)	54.6318 (0.0000)

In contrary, there are significant LM statistics of two-regime threshold cointegration test for price increase in stock index and crude oil (IXP_INC and CLP_INC), with 45.3344. It implies the presence of the threshold cointegration. For the pair on IXP_INC and CLP_INC, we find that the estimated cointegrating coefficient is $\beta=2.9157$. The estimated threshold value is $\gamma = 0.0396$ and identifies two regimes with statistically different ECM coefficients. The Wald test for equality of the ECM coefficient was significant (p-value is less than 1%). The first, or usual regime, occurs when $(IXP_INC_t - 2.9157 \times CLP_INC_t) \leq 0.0396$ and includes 91% of the observations, whereas the second, or unusual regime, includes the remaining 9% of observations and is in place when $(IXP_INC_t - 2.9157 \times CLP_INC_t) > 0.0396$.

3.5 TVECM Results

Table 4 reports the estimated coefficients for the VECM and TVECM models of price levels and price increases in stock index and crude oil index respectively. Eicker–White standard errors are also reported. However, in the TVECM models, regime1 and regime2 represent the usual and unusual regime respectively.

As presented in the Panel A in the VECM models, we first observe the cointegration of natural logarithm price levels in stock index (IXP) and crude oil markets (CLP). We find that IXP variable shows maximal error-correction effects but CLP variable shows minimal error-correction effects. There are usual clustering effects on IXP, not often on CLP. CLP closely influences IXP in the long run but opposite in direction are not found in the long run. It implies that there is negative and significant adjustment speed of IXP towards equilibrium while positive and insignificant adjustment speed of CLP towards equilibrium is found.

On the other hand, for cointegration of natural logarithm price increases in stock index (IXP_INC) and crude oil (CLP_INC), CLP_INC variable shows maximal error-correction effects but IXP_INC variable shows minimal error-correction effects. There are usual clustering effects on IXP_INC, not often on CLP_INC. CLP_INC closely influences

IXP_INC in the long run but opposite in direction are found in the long run. It implies that there is negative and significant adjustment speed of IXP_INC towards equilibrium while opposite in direction on CLP_INC is significantly negative adjustment speed.

Table 4: Results on linear VECM and TVECM

Panel A: linear VECM

$$\Delta IX_t = \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t}$$

$$\Delta CL_t = \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t}$$

Dep.Var	Price level				Price increase			
	ΔIX_t		ΔCL_t		ΔIX_t		ΔCL_t	
	IXP		CLP		IXP_INC		CLP_INC	
	Coeff.	SE.	Coeff.	SE.	Coeff.	SE.	Coeff.	SE.
λ_1	-0.0605**	0.0222	0.0165	0.0222	-0.0173**	0.0078	-0.0534**	0.0078
α_0	0.3600**	0.1286	-0.0899	0.1286	0.0068**	0.0034	0.0211**	0.0034
α_{i1}	-0.0764	0.0799	0.0356	0.0799	-0.3430	0.1909	-0.0584	0.1909
α_{i2}	0.1770**	0.0807	0.1531*	0.0807	-0.5416**	0.1665	0.0182	0.1665
α_{i3}	0.1463	0.0834	-0.1101	0.0834	-0.3569**	0.1843	-0.0142	0.1843
α_{i4}	0.3533**	0.0946	0.2274**	0.0946	-0.0594	0.1493	-0.0281	0.1493
α_{i5}	0.1697*	0.0923	0.0605	0.0923	-0.1583	0.1171	-0.1661	0.1171
β_{i1}	0.0291	0.0556	-0.0045	0.0556	0.3863**	0.1241	0.0661	0.1241
β_{i2}	-0.0487	0.0471	0.0120	0.0471	0.3360**	0.1104	0.1558	0.1104
β_{i3}	-0.2132**	0.0564	0.0790	0.0564	0.1902**	0.0990	0.0745	0.0990
β_{i4}	-0.2028**	0.0509	-0.1547**	0.0509	0.1085	0.0896	-0.0041	0.0896
β_{i5}	-0.0414	0.0508	-0.0095	0.0508	0.0659	0.0570	0.0966*	0.0570

Panel B: TVECM for price increase in index and oil (*IXP_INC*, *CLP_INC*)

$$\begin{aligned} \Delta IX_t &= \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t} \\ \Delta CL_t &= \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t} \end{aligned} \quad , \omega_{t-1} \leq \gamma$$

$$\begin{aligned} \Delta IX_t &= \lambda_1 \omega_{t-1} + \alpha_{10} + \sum_{i=1}^m \alpha_{1i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{1j} \Delta CL_{t-j} + u_{1t} \\ \Delta CL_t &= \lambda_2 \omega_{t-1} + \alpha_{20} + \sum_{i=1}^m \alpha_{2i} \Delta IX_{t-i} + \sum_{j=1}^n \beta_{2j} \Delta CL_{t-j} + u_{2t} \end{aligned} \quad , \omega_{t-1} > \gamma$$

	Regime1				Regime2			
%of obs	0.9097				0.0903			
Dep.Var	ΔIX_t		ΔCL_t		ΔIX_t		ΔCL_t	
	IXP_INC		CLP_INC		IXP_INC		CLP_INC	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
λ_1	0.0517**	0.0285	0.2472**	0.0452	-1.6747**	0.4505	-0.6562*	0.3227
α_0	0.0062*	0.0026	0.0094**	0.0036	0.0347*	0.0176	0.2444**	0.0126
α_{i1}	-0.1415	0.0927	-0.4181**	0.1004	0.5853	0.3763	-2.0110**	0.2695
α_{i2}	-0.2440	0.0930	-0.2926**	0.1052	1.3224	0.9828	1.7585*	0.7038
α_{i3}	-0.1550	0.0970	-0.2530*	0.1174	0.5857	0.5266	-1.9983**	0.3771
α_{i4}	0.0487	0.0781	-0.1996	0.1307	-0.2422**	0.0595	0.0255	0.0426
α_{i5}	0.0523	0.0644	-0.3638**	0.1322	0.4862*	0.1983	1.6216**	0.1420
β_{i1}	0.2031*	0.0858	-0.0580	0.1061	-8.8658**	0.8235	9.4329**	0.5897
β_{i2}	0.1697*	0.0709	0.0577	0.0887	-10.2374**	1.2081	5.1255**	0.8652
β_{i3}	0.1740**	0.0671	-0.0111	0.0802	-9.8162	1.1669	3.934**	0.8356
β_{i4}	0.0724	0.0669	-0.0794	0.0653	-12.0892**	1.3731	-6.8561**	0.9833
β_{i5}	0.0272	0.0422	0.0555	0.0544	-0.0915	0.2521	0.3861*	0.1805

Note: The optimal lag is 5 based on SIC. Eicker–White covariance matrix estimation method is used. ** is at 1% significant level. * is at 5% significant level.

As shown in the Panel B in the TVECM models, due to nonexistence of the threshold cointegration of natural logarithm price levels in stock index (IXP) and crude oil markets (CLP), we would only investigate the threshold cointegration of natural logarithm price increases in stock index (IXP_INC) and crude oil markets (CLP_INC).

In the usual regime, variable IXP_INC show minimal error-correction effects but variable CLP_INC show maximal error-correction effects. In addition, one finding of great interest is the positive estimated error-correction effects of IXP_INC and CLP_INC. However, both variables show maximal dynamics, with in the usual regime the estimated coefficient showing a substantially larger impact. There are clustering effects on IXP_INC, not on CLP_INC. On the other hand, when the gap between IXP_INC and CLP_INC is above a critical threshold $\gamma = 0.0396$, the error-correction effects of both variables in the equation become statistically significant and positive, with the estimated coefficient showing a substantially larger impact. Additionally, there are clustering effects on IXP_INC and CLP_INC respectively.

The estimated coefficients of ω_{t-1} of each regime denote the different adjustment speeds of two series towards equilibrium. We find the error-correction effects of IXP_INC and CLP_INC variables in the unusual regime are larger than in the usual regime, suggesting larger adjustment speed of IXP_INC and CLP_INC towards equilibrium in the unusual regime. Two possible reasons are provided. In the unusual regime price increase in stock index and the subsequent impact on price increase in crude oil index may be that China is the world's biggest consumer for oil and China's economic growth moderates. Another reason is that in the unusual regime one factor other than supply and demand, now impacts

the oil price increases. Therefore, our findings shed lights on asymmetric adjustment speeds of two series towards equilibrium.

In Figure 2, we plot the error-correction effect, the estimated regression functions of IXP_INC_t and CLP_INC_t as a function of w_{t-1} , holding the other variables constant. To note that ix_inc and oil_inc are presented by price increases in stock index and crude oil index. In the figure, you can see the flat near-zero error-correction effect on the left size of the threshold, and on the right of the threshold, the sharp negative relationships, especially for the IXP_INC equation.

Finally, the transitory effects expressed by the differenced terms highlight significant or moderate autoregressive behavior for IXP_INC , whereas the same is more accentuated for the CLP_INC .

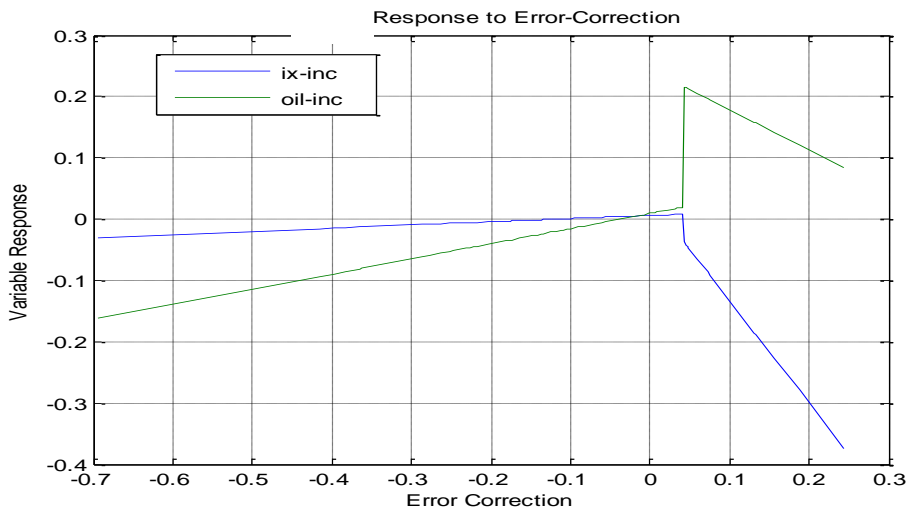


Figure 2: Price increases in stock index and crude oil index variance response to error correction

3.6 Dynamics of Stock Index and Crude Oil in the VECM and TVECM

In this section we test the causality of the two time series for stock index (IX) and crude oil (CL) variables using a Granger causality Wald test (Granger, 1969; Granger et al., 2000), which tests the null hypothesis of no causal relationship between the two time series.¹⁰ The results on Granger causality in the VECM and TVECM are presented in the Table 5. In the TVECM, regime1 and regime2 represent the usual and unusual regime respectively.

From the Panel A in the Table 5 in the VECM, there is the evidence that price level in crude oil (CLP) Granger causes price level in stock index (IXP) in the short and long runs but no evidence of IXP Granger causing CLP in the short and long runs. On the other hand, we find absence of short-run dynamics between price increases in stock index and crude oil (IXP_INC and CLP_INC) in the short run. However, we find long-run dynamics between

¹⁰This approach is also used by Fung and Patterson (1999) and Hsueh et al. (2008), etc.

IXP_INC and CLP_INC in the long run, suggesting feedback dynamics of IXP_INC and CLP_INC in the long run.

As shown in Panel B of Table 5 in the TVECM, we examine the short- and long-run dynamics of IXP_INC and CLP_INC in the usual and unusual regimes. We find absence of short-run dynamics between IXP_INC and CLP_INC in the short run in the usual regime but long-run dynamics from IXP_INC to CLP_INC in the long run is found. On the other hand, in the unusual regime, IXP_INC Granger causing CLP_INC is detected in the short run. Additionally, there are feedbacks for IXP_INC and CLP_INC in the long run in the unusual regime, with larger magnitude of the F-statistic on IXP_INC Granger causing CLP_INC than that on CLP_INC Granger causing IXP_INC. Specifically, our findings in the short-run and long-run unusual regime are consistent with the argument of Hamilton (2009b), that demand-side shock deriving from industrialization of countries such as China could have a significant impact in oil price. Hence, as expected, IXP_INC shows the evidence of market leadership, whereas IXP_INC and CLP_INC adjust to long-run equilibrium as a consequence.

Table 5: Results on Granger causality in VECM and TVECM

Panel A: VECM

Alternative hypothesis		price level in index and oil	price increase in index and oil
$H_1: CL \rightarrow IX$	Short run	4.3422**	2.0982
	Long run	5.0879**	2.3669*
$H_1: IX \rightarrow CL$	Short run	0.8382	0.5238
	Long run	0.9302	11.6052**

Panel B: TVECM

Alternative hypothesis		price level in index and oil		price increase in index and oil	
		Regime1	Regime2	Regime1	Regime2
$H_1: CL \rightarrow IX$	Short run	-	-	1.5832	12.0964
	Long run	-	-	1.8629	9.7953**
$H_1: IX \rightarrow CL$	Short run	-	-	0.7718	91.7115**
	Long run	-	-	12.0579**	53.7469**

Note: F-statistics are reported. ** is at 1% significant level; * is at 5% significant level. IX and CL represent stock index market and crude oil market. “-” notes the nonexistence of the threshold cointegration of natural logarithm price levels in stock index (IXP) and crude oil markets (CLP).

4 Conclusions

This paper examines threshold cointegration and dynamics of Shanghai A stock index and Brent crude oil in the framework of a threshold vector error correction model (TVECM). There is the record of structural breaks in crude oil price data, like the increase in the price on crude oil since 2003, its sharp spike at \$142 per barrel in July 2008 and its subsequent collapse in the autumn of 2008. On the other hand, there is the record of structural breaks in stock index price data, like an upward trend since 2006, reaching 6,124.04 points on

October 16, 2007, and its subsequent collapse in mid-2008. Our monthly sample period is from Jan. 2000 to Jul. 2012, with 150 observations.

A test for the null of no cointegration in the context of the threshold cointegration model is conducted. This testing problem is quite complicated as the null hypothesis implies that the threshold variable (the cointegrating error) is non-stationary, rendering current distribution theory inapplicable. Two regimes are implied by the model and divided into the usual and unusual regimes. Our findings show that while conventional methods fail to detect significant dynamics between price increases in Chinese stock index and Brent crude oil index in the usual and unusual regimes, application of this extended approach reveals the existence of a threshold cointegration and dynamics in the TVECM. Furthermore, our results of the threshold cointegration test identify two regimes with statistically different ECM coefficients.

Consistent with prior findings in the U.S. and counter to findings for the European countries, both price increases in Chinese stock index and Brent crude oil (IXP_INC and CLP_INC) show different error-correction effects and dynamics, with larger adjustment speed of IXP_INC and CLP_INC towards equilibrium in the unusual regime and the estimated coefficient for IXP_INC showing a substantially larger impact in the unusual regime. Additionally, our findings in China suggest Granger causality running from stock index price increase to crude oil price increase in the short- and long-run in the unusual regime but Granger causality running to stock index price increase from crude oil price increase only in the long-run unusual regime. In other words, during the usual and unusual regime, Chinese stock index price increase has a predominant role in the crude oil markets. Malik and Ewing (2009) show lagged oil prices act as a risk factor for the stock markets. However, Miller and Ratti (2009), Lescaroux and Mignon (2008), Nordhaus (2007), Blanchard and Gali (2007), Bernanke et al. (1997) conclude that for more than a decade now, oil prices do not affect stock prices.

Additionally, one finding of great interest is the positively larger estimated error-correction effects of CLP_INC than IXP_INC in the usual regime but the negatively larger estimated error-correction effects of IXP_INC than CLP_INC in the unusual regime. It implies that there are different and strong asymmetries between the two regimes in the speed of adjustment to the short- and long-run equilibrium for price increases in stock index and crude oil.

Therefore, our results should highlight the critical importance of using TVECM in empirical studies on threshold cointegration and dynamics of Chinese stock index and Brent crude oil index. Chinese stock index price increase seems to affect Brent crude oil index price increase at the existence of threshold cointegration but opposite in direction at the nonexistence of threshold cointegration.

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