Tzu-Yi Yang

Corresponding author

Ming Chi University of Technology,
Department of Business
and Management,
Taiwan

✉ tyyang@mail.mcut.edu.tw

Thieu Thi Thanh Ha

Ming Chi University of Technology,
Department of Business
and Management,
Taiwan

✉ thieuthanhha1402@gmail.com

Chia-Wei Yen

Formosa Petrochemical Corporation,
Oil and Gas E&P Department,
Taiwan

✉ William-Yen@fFpcc.com.tw

Oil Threshold Value between Oil Price and Production

Summary: This study proposes a panel smooth transition regression (PSTR) model to investigate the nonlinear relationship between crude oil prices and crude oil production in 122 countries, both OPEC and non-OPEC, from March 1994 to October 2015. The statistical test for the existence of a threshold effect indicates that the relationship between oil prices and oil production is nonlinear, with different changes over time among the oil price and transition variables. Additionally, a threshold value exists. Furthermore, crude oil price volatility exhibits asymmetric responses to production volatility by fluctuating above or below the threshold value. Finally, when crude oil price volatility with a lag of two periods exceeds the threshold value, crude oil production changes have a positive impact on crude oil price volatility. In contrast, when crude oil price volatility with a lag of two periods is less than the threshold value, crude oil production changes have a negative impact on price volatility.

Key words: Panel smooth transition regression (PSTR) model, Threshold effects, Crude oil prices, Crude oil production, Nonlinear relationship.

JEL: E46, K32.

Understanding crude oil price movement is crucial to economic activities (Jungwook Park and Ronald A. Ratti 2008; Yanan He, Shouyang Wang, and Kin Keung Lai 2010; Stefan F. Schubert and Stephen J. Turnovsky 2011; Saidi Atanda Mustapha and Luqman Adedamola Sulaiman 2015). There are three oil surges: in 1973, from 1979 to 1980, and from 2003 to 2008. Fabian Kesicki (2010) found that the first two oil crises were rooted primarily in the market power of the Organization of Petroleum Exporting Countries (OPEC) and in political issues, whereas all three surges were spurred by high growth in demand. The price of crude oil is determined by market supply and demand (Jochen H. F. Güntner 2014). Recently, there has been increasing recognition that flow demand and supply shocks significantly contributed to most major oil price increases. Lutz Kilian (2009) showed that changes in crude oil prices were driven by demand shocks rather than supply shocks. This conclusion was later reconsidered by Marek Kolodzeij and Robert K. Kaufmann (2014), who found that it was not robust to alternative specifications. Their results differ from Kilian (2009) due to the aggregation of OPEC and non-OPEC production, inclusion of transportation costs, and use of a cointegrated vector autoregressive model (CVAR). The Arab Embargo (1973-1974), the Iranian Revolution (1978-1979), and the Persian Gulf War (1990-1991) caused considerable production losses by influencing the flow of

supplies, which led to dramatic increases in crude oil prices. However, studies of flow supply shocks or the impact of oil supply on its prices are limited.

Many studies focus on forecasting crude oil production but these lack the intent to recognize the circumstances around crude oil price changes (Gaetano Maggio and Gaetano Cacciola 2009; Mohsen Ebrahimi and Nahid Cheshme Ghasabani 2015). Importantly, the volatility of crude oil prices is exerted asymmetrically on economic activities (Ana María Herrera, Latika Gupta Lagalo, and Tatsuma Wada 2015), which raises the question of whether it is possible to obtain the (threshold) price by analyzing crude oil production and even examining the state in which crude oil is produced. In addition, there has been an increase in the number of studies related to the threshold effects of oil prices (Ahmad Hassan Ahmad and Ricardo Moran Hernandez 2013; Debdatta Pal and Subrata Kumar Mitra 2015). Due to the use of threshold cointegration in the panel framework, there is a lack of literature on the relationship between the price of crude oil and its production.

Recently, the world has witnessed a considerable drop in oil prices, driven by many factors, importantly, the lack of an OPEC prediction about oil production. As mentioned in the U.S. Energy Information Administration (EIA 2016a) Short-Term Outlook, meetings of OPEC members were held for the purpose of freezing oil production. Thus, estimating the global effects of crude oil production could prevent the occurrence of extreme crude oil prices. However, crude oil price-production relationship must be calculated first. Hence, this study further investigates the nonlinear effects of crude oil production by analyzing the threshold oil price value.

Among many well-known models, the threshold model is suitable for detecting nonlinearity. Due to the required analysis of panel data containing cross-sectional and time-series sections, this research employs the panel smooth transition regression (PSTR) model of Andrés González, Timo Teräsvirta, and Dick van Dijk (2005), which helps to detect asymmetric effects of crude oil production on oil prices and on the threshold level from March 1994 to October 2015. Our study answers two main questions: (i) whether there are threshold effects between the price of crude oil and its production; and (ii) whether there are any patterns in crude oil prices based on the state in which it is produced. These answers will contribute greatly to the literature and to practice, for examples, helping governments, policy makers and OPEC countries to develop appropriate plans to maintain crude oil prices or avoid unpredictable surges.

This paper comprises four sections. Section 1 describes the relevant historical literature. Section 2 illustrates the data and methodology. Section 3 presents the empirical results. Section 4 presents the conclusion and contributions to the literature.

1. Literature Review

Although crude oil production significantly affects its price, the crude oil price-production relationship has not been explored in detail. Many previous studies strongly emphasize the impact of oil consumption on price and omit production from consideration. Recently, several papers reconsidered the role of crude oil production in its price. The results from Granger causality tests in Andres Gallo et al. (2010) generally indicated that the recent surges in oil prices are connected to oil production rather than consumption. Certain emerging countries, such as China, consume large quantities of

oil, which could cause oil price fluctuations in the future. In addition, the level of demand for oil depends on particular countries. Hence, there is a scarcity of previous research based on changes in consumption, which have been responsible for previous fluctuations in oil prices. Additionally, Robert L. Linn (2006) concluded that the major effect of oil surges was to decrease planned production levels. Recently, Nicholas Apergis, Bradley T. Ewing, and James E. Payne (2016) indicated that the crude oil prices and rig counts positively influence oil production. Consequently, the investigative movement stops at the effect of crude oil price on its production, which is positive. However, the effect of crude oil production on crude oil prices and whether this effect is linear or nonlinear remain unknown.

Regarding the scope of empirical analyses relating to the threshold model, most studies focus primarily on the asymmetric effects of changes in crude oil prices on refined products, exchange rates, stock prices or other economic indexes rather than crude oil production. Bwo-Nung Huang, M. J. Hwang, and Hsiao-Ping Peng (2005) explored the asymmetric impact of oil price movement and volatility on economic variables including output, stock returns and interest rates in the United States (US) (a net oil importer), Canada (a net oil exporter), and Japan (a pure oil importer) from 1970 to 2002. Later, Jer-Yuh Wan and Chung-Wei Kao (2015) attempted to analyze the non-linear correlation between oil and financial variables with a structural threshold vector autoregressive model (STVAR) model using monthly data on US interest rates, US dollar exchange rates, and financial stress indexes from 1975 to 2014. Consequently, there was an asymmetric impact of shocks in different financial stress regimes. Specifically, shocks are larger in stressed regimes than in normal regimes. Depreciation of the US dollar is prone to cause an increase in oil prices, whereas a positive oil shock can cause an increase in the US dollar. Empirical research from Yu Shan Wang and Yen Ling Chueh (2013) on the relationship between crude oil prices and other financial indicators (including the interest rate, the US dollar, and gold) from 1989 to 2007 shows the influence of these variables on each other. Several threshold models were adopted, including a momentum threshold autoregression (MTAR) model (to identify the optimal threshold level of each criterion) and a threshold error correction model (TECM) (to analyze the threshold effects). The authors suggested that above and below the threshold values, gold and crude oil prices influence not only each other but also the interest rate. In addition, the present value of the US dollar has no influence on the price of crude oil in the future. Ahmad and Hernandez (2013) detected the asymmetric adjustment between real oil prices and the real exchange rate of domestic countries with respect to the US dollar from 1970 to 2012. Their methodology included the threshold autoregressive (TAR) method and the MTAR method. Their results indicated the cointegration of five countries – Brazil, South Korea, Mexico, Nigeria, and the United Kingdom (UK) – and the European Union. In particular, Brazil, Nigeria and the UK exhibited greater adjustments in response to positive shocks than to negative shocks, which means that an increase in exchange rates following an increase in oil prices is eliminated faster than an increase in exchange rates following a decrease in oil prices. The topic of nonlinear cointegration between international crude oil prices and the exchange rate was also recently discussed by Sajal Ghosh and Kakali Kanjilal (2016). In the stock market field, Hui-Ming Zhu, Su-Fang Li, and Keming Yu (2011)

adopted a panel threshold cointegration framework to study the linkages between crude oil prices and the stock markets of 14 countries, and their main finding indicated the presence of asymmetric threshold relations between crude oil prices and the stock markets. For example, crude oil prices rise 1% following a 0.43% increase in stock prices. In contrast, a 1% increase in stock prices leads to a 0.54% change in oil prices. Additionally, the adoption of a threshold generalized autoregressive conditional heteroskedasticity (TGARCH) model was used by Tzu-Yi Yang and Yu-Tai Yang (2015) to investigate the asymmetric effects of news on stock market behavior. Xiao Qin, Chunyang Zhou, and Chongfeng Wu (2016) investigated a rockets and feathers theory with a multiple threshold error-correction model (MTECM) and found a nonlinear relationship in the short-term between crude oil and gasoline prices in commodity and financial markets but not in refinery markets.

Regarding agriculture, Valeri Natanelov et al. (2011) first ran the vector error correction model (VECM) and the threshold vector error correction model (TVECM) based on Bruce E. Hansen and Byeongseon Seo (2002) identified linkages between crude oil prices (Brent) and the cocoa, wheat, and gold markets. There was no cointegration or threshold effect of the oil-corn relationship, which implies that biofuel policy buffers the co-movement of the oil and corn markets when crude oil futures prices exceed an estimated threshold level (US $75 per barrel in July 2006).

With respect to oil prices, Yudong Wang and Wu (2013) reconsidered the cointegration relationship between spot and future crude oil (West Texas Intermediate (WTI)) prices because many previous studies had shown linearity in a long-run equilibrium adjustment process. Instead of a conventional framework, they used a nonlinear TVECM and a threshold Lagrange Multiplier (LM) test proposed by Hansen and Seo (2002). In contrast to the linear results found in Søren Johansen (1988), they found a cointegration relationship that exhibited threshold effects. When the futures basis exceeds a threshold value, the crude oil spot and futures prices are cointegrated. Futures prices are expected to drive spot prices in the short-term, whereas both spot and futures prices can drive each other to long-run equilibrium levels. Hassan Belkacem Ghassan and Hassan Rafdan AlHajhoj (2016) calculated the asymmetric dynamics of OPEC and non-OPEC crude oil prices from 1973 to 2013 by running error correction model (ECM), TAR, and MTAR models with a threshold cointegration and component generalized autoregressive conditional heteroskedasticity (CGARCH) error framework. They detected differences in the speed of adjustment. In the case of positive deviation, for the long-run equilibrium, the OPEC crude oil price adjustment process is slower than the process for non-OPEC prices, which contrasts with the short-term equilibrium. This result implies that OPEC producers have less of an impact on crude oil prices in the long-term than non-OPEC producers have in the short-term. Moreover, both OPEC and non-OPEC prices have the same reaction to a negative regime when the oil price is too low.

Many threshold models have been adopted to analyze nonlinearity, including TAR, the Markov Switching (MS) model, the neural network (NN) model, smooth transition autoregressive (STAR), MTAR, TECM, and the PSTR model. As shown in Burcu Kiran (2012), the TAR model can derive endogenous threshold effects. However, the TAR model is not suitable for this study due to its time-series feature.

Additionally, the traditional threshold models for two regimes and a zero threshold level fail to expose asymmetric patterns (Qin, Zhou, and Wu 2016). The switching process of economic variables in an MS model is radical and discrete just for its actual movement. The NN model judges the regime process through the human brain and thus lacks objective meaning. Depending on the research purpose, these models are used to examine time series and panel data. The PSTR model is helpful in handling panel data with cross-sectional and time-series characteristics. The advantages of the PSTR model are clearly indicated in a number of studies, as mentioned below.

The recent empirical literature indicates that the adoption of the PSTR model to examine threshold effects has become a focal point. In the oil price field, Marc Joëts and Valérie Mignon (2012) used the PSTR model to study the cointegration relationship among the prices of oil, gas, coal, and electricity at 35 maturities because PSTR can model the nonlinear behavior of the forward energy price adjustment process to the equilibrium value given by the estimated long-term relationship between the prices of oil, gas, coal and electricity. The findings showed that the forward oil price adjustment process to its equilibrium value is nonlinear and asymmetric. The estimated threshold is 36%, which implies an asymmetric phenomenon wherein the adjustment process is at regime for high under-valuations, not over-valuations. Apergis and Payne (2014) detected the cointegrated relationship among renewable energy consumption *per capita*, real gross domestic product (GDP) *per capita*, carbon emission *per capita*, real coal prices, and real oil prices in seven Central American countries from 1980 to 2010. The estimated value of the threshold was -0.00175, reflecting the extreme regimes in the negative and positive values of renewable energy consumption *per capita*. Their results revealed that in the post-2002 period, the effect of renewable energy consumption *per capita* – specifically, on real coal and oil prices – is more sensitive to real GDP *per capita* than to carbon emissions *per capita*. In addition, Wang (2013) investigated the smooth transition effects of oil price changes on personal consumption expenditures in the G7 economies using quarterly data from 2005 to 2010. Using the PSTR model of González, Teräsvirta, and Van Dijk (2005), the author found a nonlinear, asymmetric relationship between crude oil price fluctuation and personal consumption expenditures. The estimated threshold level of oil prices after a lag of one period was 0.92, and the transition speed was 4.8, implying different effects of oil price changes on personal expenditures in cases above and below the threshold level. Below the threshold level, a 1% increase in oil prices will lead to a 0.6893% decrease in personal expenditures in G7 countries. In contrast, each 1% decrease in oil prices will increase the marginal effects of personal consumption expenditures by 0.0517%. Jean-Pierre Allegret et al. (2014) focused on the price of oil in their study of current account relationships across 27 oil-exporting countries from 1980 to 2010. As discussed in this paper, the PSTR model offers many advantages, including that it allows this relationship to vary over the time period associated with the level of financial development and that it estimates the threshold value of financial development. By following the PSTR model of González, Teräsvirta, and Van Dijk (2005), the dependent variable and independent variable are the current account to GDP ratio and the oil price, respectively. The transition variable was expressed by the degree of financial development. The results indicated a nonlinear impact of oil price fluctuation on the current account

position according to the level of financial development of each country. The threshold value of financial depth is 25%. Oil price variations have a stronger effect on the current account position in less financially developed oil exporters than in exporters with a high degree of financial depth.

A review of the above studies reveals a gap in the research on nonlinearity and the asymmetric responses of the price of crude oil to its production and shows that the threshold model is typically adopted. This paper sheds new light on the nonlinear relationship between the price of crude oil and its production using a panel threshold model, thereby addressing the gap in the research and making both practical and empirical contributions to the field. More specifically, this study aims to detect nonlinear effects on the relationship between crude oil prices and crude oil production by adopting the PSRT model of González, Teräsvirta, and Van Dijk (2005). Details regarding the data, methodology, and model used will be provided in the following section.

2. Data and Methodology

2.1 Database

The dataset includes monthly oil price and production data from March 1994 to October 2015. Data for oil prices and oil production are obtained from databases of the International Monetary Fund (IMF 2016)[1] and the EIA (2016b)[2], respectively. Oil price and production are measured in dollars per barrel and thousands of barrels per day, respectively.

As mentioned in the EIA (2014)[3], the most significant benchmarks in crude oil pricing are Dubai, Brent, and WTI. Based on their specific characteristics, the EIA classifies these benchmarks based on the places where oil is priced. Brent and WTI are mostly used in Asia, Europe, and America. Hence, the data structure is divided into three regimes: Asia, Europe, and America. Therefore, the panel dataset of crude oil prices corresponds to the oil benchmarks used by the regimes.

This study leverages the EIA database by ascertaining monthly crude oil production in 12 OPEC countries and 110 non-OPEC countries, for 122 countries in total. These countries are listed in Table 1. The countries are classified as OPEC or non-OPEC countries in all years based on their status in the current year.

The data structure is cross-sectional among the crude oil production of these countries and crude oil prices. Thus, it requires the correct matching of data on crude oil production in each country to the appropriate oil benchmark (Dubai, Brent, and WTI). Specifically, Brent is used to price light, sweet crude oil that is produced and

---

[1] **International Monetary Fund (IMF).** 2016. Advanced Retrieval and Econometric Modeling System (AREMOS).
http://net.aremos.org.tw/search/view.php?db=ENG&desc=%E5%8F%B0%E7%81%A3%E5%9C%B0%
E5%8D%80%E8%83%BD%E6%BA%90%E7%B5%B1%E8%A8%88%E8%B3%87%E6%96%99%E5
%BA%AB (accessed January 10, 2016).
[2] **U.S. Energy Information Administration (EIA).** 2016b. Spread Narrows between Brent and WTI Crude Oil Benchmark Prices. www.eia.gov/todayinenergy/detail.php?id=12391 (accessed October 11, 2016).
[3] **U.S. Energy Information Administration (EIA).** 2014. Benchmarks Play an Important Role in Pricing Crude Oil. www.eia.gov/todayinenergy/detail.cfm?id=18571 (accessed October 28, 2014).

traded in Europe, the Mediterranean, Africa, Australia and certain countries in Asia, including Indonesia, Malaysia, and Vietnam. WTI is an oil benchmark for medium, sour crude oil produced in the Gulf of Mexico; light, sweet crude oil produced in the United States; and imported crude oil produced in Canada, Mexico and South America. Finally, Dubai is the benchmark for medium, sour crude oil that is produced in the Middle East and exported to Asian markets.

Table 1 OPEC and Non-OPEC Countries

OPEC and non-OPEC	Regimes	Countries
OPEC (12 countries)	Asia	Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates
	Europe	Algeria, Angola, Libya, Nigeria
	America	Ecuador, Venezuela
Non-OPEC (110 countries)	Asia	China, Oman, Yemen, Bangladesh, Brunei, Burma (Myanmar), Cambodia, Hong Kong, India, Japan, Korea (South), Mongolia, New Zealand, Pakistan, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand, Timor-Leste, Bahrain, Israel, Syria
	Europe	Egypt, Norway, Russia, United Kingdom, Indonesia, Australia, Malaysia, Gabon, Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, Former Serbia and Montenegro, France, Germany, Germany (offshore), Greece, Hungary, Ireland, Italy, Netherlands, Netherlands (offshore), Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Vietnam, Benin, Cameroon, Chad, Congo (Brazzaville), Congo (Kinshasa), Côte d'Ivoire (Ivory Coast), Equatorial Guinea, Ethiopia, Ghana, Malawi, Mauritania, Morocco, South Africa, Sudan and South Sudan, Tunisia, Zimbabwe, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
	America	Canada, Mexico, United States, Chile, Brazil, Argentina, Colombia, Barbados, Belize, Bolivia, Costa Rica, Cuba, El Salvador, Guatemala, Jamaica, Nicaragua, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay

Source: EIA (2014) and this research arrangement.

2.2 Description of Variables

This work applies the PSTR model developed by González, Teräsvirta, and Van Dijk (2005). This nonlinear model contains three main parts – the dependent variable, transfer variable and independent variable – which allows the sequence to move smoothly in two regimes with different values for the transition variable.

The aim of this study is to analyze the threshold effect of crude oil prices on its production with the PSTR model, using changes in crude oil price and production as the dependent and independent variable, respectively. The following sections describe these data.

The dependent variable indicates monthly crude oil price volatility and can be written as $\Delta P_{i,t}$. This variable represents crude oil price volatility that is consistent with an oil benchmark at a specific time where $i = 1, 2, 3$ denotes the oil benchmark – Dubai, Brent, and WTI – and $t = 1, 2, 3 \dots$ denotes time. $\Delta P_{i,t}$ is the monthly crude oil price volatility of an oil benchmark (Dubai, Brent, or WTI) in period (t). The value of the dependent variable at the current time is evaluated as the crude oil price at present minus the price in the previous month.

The independent variable is implied by changes in monthly world crude oil production, which is the total of OPEC and non-OPEC crude oil production. It is signified by $\Delta CO_{i,t}$, where i represents the cross-section of countries $(i = 1,2,3 \dots N)$ and t is the time period $(t = 1,2,3 \dots T)$. ΔCO stands for changes in crude oil production.

$\Delta CO_{i,t}$ denotes changes in the crude oil production of a specific regime (i) at time (t). The value of changes in monthly global crude oil production can be calculated as the difference between the present data and previous data.

The transfer variable plays an important role in the PSTR model and is a previous crude oil transition function that is denoted by $G(q_{it}; \gamma, c)$. Its value can be expressed by crude oil volatility with a lag of two periods, $\Delta P_{i,t-2}$. Specifically, $\Delta P_{i,t-2}$ denotes the crude oil price volatility of a particular oil benchmark (i) at a specific time $(t-2)$. To calculate the crude oil price-production relationship, the data flow from March 1994 to October 2015 is chosen because of a requirement in the previous data for $\Delta P_{i,t-2}$. The transition function describes the smooth switching process of the crude oil price. The optimal lagged transition variable is determined by the minimum Akaike information criterion (AIC) and Bayesian information criterion (BIC). The transition variable can be written as follows:

$$G(q_{it}; \gamma, c) = \{1 + exp[-\gamma \prod_{j=1}^{m}(q_{i,t} - c_j)]\}^{-1}, \qquad (1)$$

where $\gamma > 0$ and $c_1 \leq c_2 \leq \cdots \leq c$. When $m = 1$ and $\gamma \to \infty$, the PSTR model is reduced to a panel transition regression model. González, Teräsvirta, and Van Dijk (2005) considers only two cases, $m = 1$ and $m = 2$, to capture nonlinearities caused by regime switching.

As noted by González, Teräsvirta, and Van Dijk (2005), the transition function is bounded between 0 and 1. Additionally, the extreme values are consistent with the regression coefficients β_0 and $\beta_0 + \beta_1$. In addition, q_{it} is the observable variable that determines the value of the transition function $G(q_{it}; \gamma, c)$ and thus the effective regression coefficient $\beta_0 + \beta_1 G(q_{it}; \gamma, c)$ for individual (i) at time (t). Table 2 presents the names, codes, measurements, and data sources of the variables.

Table 2 Data Measurement

Name	Code	Measurement	Data source
Crude oil price volatility	$\Delta P_{i,t}$	Crude oil price at present minus this value in the previous month of a specific oil benchmark (i).	IMF (2016)
Crude oil price volatility with a lag of two periods	$\Delta P_{i,t-2}$	Crude oil price at present minus this value in the previous two months of a specific oil benchmark (i).	IMF (2016)
Changes in crude oil production	$\Delta CO_{i,t}$	Value of crude oil production of regime (i) at present minus this value in the previous month.	EIA (2016b)

Notes: (1) $\Delta P_{i,t}$ presents the monthly crude oil price volatility of a specific oil benchmark (i) at time (t). $\Delta P_{i,t-2}$, which is a lag of two periods of $\Delta P_{i,t}$, means the monthly crude oil price volatility of oil benchmark (i) at time $(t-2)$. $\Delta CO_{i,t}$ is the monthly crude oil production of regime (i) at time (t); (2) The sampling period is from March 1994 to October 2015.

Source: Authors' elaboration.

2.3 Methodology

2.3.1 The Panel Smooth Transition Regression Model

As discussed by Wang (2013), the PSTR model is more flexible than the panel threshold regression (PTR) model. Indeed, the PSTR model offers the advantage of allowing crude oil price volatility regression coefficients to vary across countries and time depending on the level of the transition variable. PSTR also allows for smooth changes

in cross-sectional correlations, cross-sectional heterogeneity, and the time instability of the impact. PSTR is especially useful when measuring threshold effects because it shows different responses of the independent variable to the dependent variable to coincide with levels above, below, and equal to threshold value. Therefore, it is appropriate to adopt the method developed by González, Teräsvirta, and Van Dijk (2005) to simultaneously evaluate nonlinear effects and resolve heterogeneity problems. The model can be written as follows:

$$\Delta P_{i,t} = \alpha_i + \beta_1 \Delta X_{i,t} + \beta_2 \Delta X_{i,t} + G(q_{it}; \gamma_j, c_j) + \mu_{it}, \qquad (2)$$

where $j = 1,2,\dots,r$ denotes the number of transition functions, $(r+1)$ is the number of regimes, and t is the time period $(t = 1,2,3 \dots T)$.

Denoting the dependent, independent, and transition variables above, the PSTR model is given by:

$$\Delta P_{i,t} = \alpha_i + \sum_{i=1}^{n} \beta_1 \Delta CO_{i,t} + \sum_{j=0}^{\gamma} \beta_j \Delta CO_{i,t} G(q_{it}; \gamma_j, c_j) + \mu_{it}, \qquad (3)$$

where $j = 1,2,\dots r$ denotes the number of transition functions and $(r+1)$ is the number of regimes. $G(q_{it}; \gamma_j, c_j)$ is a transition function with q_{it} as a transition variable and γ, c as the transition parameter and transition threshold value. $\Delta P_{i,t}$ is the monthly crude oil price volatility of a particular oil benchmark (Dubai, Brent, or WTI) in period (t). It is a dependent variable. $\Delta CO_{i,t}$ represents changes in the crude oil production of specific regime (i) at time (t). It is an independent variable.

2.3.2 Estimation and Specification Test

There are three main phases in the testing process. First, the panel unit root test is employed to test a stationary set of variables. The explanation may be that the characteristics of variables across nations and time series result in a nonstationary series. Then, if the test shows stationary characteristics of variables, the test of nonlinearity will be used to answer the major question presented at the beginning of this paper – that is, whether crude oil prices and crude oil production have a nonlinear relationship. If not, then the next stage will be implemented, which is the examination of the number of threshold points in the relationship between crude oil price and production.

González, Teräsvirta, and Van Dijk (2005) proposed the PSTR model to detect nonlinearity. The PSTR model equation is shown by Equation (3). However, it is first necessary to test whether the sample model reports nonlinear effects. The null hypothesis is:

H₀: The linear model does not have transition effects.
H₁: The PSTR model has at least one threshold value $(r = 1)$.

If the null hypothesis of linearity is not rejected, there are transition effects. Thus, the next step is to determine the number of transition functions. If the hypothesis for one threshold value is rejected, then the model has at least one threshold value. In this case, a test to confirm the number of threshold values is required. The testing procedure is continued until the hypothesis without an additional threshold is not rejected. Finally, to estimate the parameters of Equation (3), the individual-specific means are removed and the nonlinear least squares method is applied. Here, $PSSR_0$ denotes the

panel sum of squared residuals under the null hypothesis (the linear panel model with individual effects) and $PSSR_1$ denotes the panel sum of squared residuals under the alternative hypothesis (the PSTR model with two regimes). The corresponding LM-statistic is given by the following:

$$LM_F = [(PSSR_0 - PSSR_1)/K]/[PSSR_0/TN - N - K], \qquad (4)$$

where K is the number of explanatory variables. Under the null hypothesis, the LM-statistic has an asymptotic $\chi^2(K)$ distribution.

3. Empirical Results

3.1 Descriptive Statistics

The observed variables for crude oil price and crude oil production during the given time period are displayed in Table 3. The minimum, maximum and average values and the standard deviations are provided in the columns corresponding to each variable.

Table 3   Descriptive Statistics for Crude Oil Price and Crude Oil Production, 1994-2015

Variables	$\Delta P_{i,t}$	$\Delta P_{i,t-2}$	$\Delta CO_{i,t}$
Dubai			
Max	15.48	24.12	1263.627
Min	-27.35	-44.59	-1620.513
Avg	.1300769	.2623077	36.57098
STD	4.640755	389.4627	389.4627
Brent			
Max	13.5	22.61	740.115
Min	-26.22	-45.82	-1299.9
Avg	.137	.2558077	14.62628
STD	4.993553	8.340109	313.9152
WTI			
Max	13.55	21.31	969.899
Min	-27.33	-46.65	-1701.742
Avg	.1208462	.2262308	26.83075
STD	4.904018	8.19124	267.6492
Total			
Max	15.48	24.12	1263.627
Min	-27.35	-46.65	-1701.742
Avg	.1293077	.2481154	26.00933
STD	4.842198	8.153896	327.249

Notes: Same as Table 2.

Source: Authors' elaboration based on data from EIA (2016b).

For the first variable, $\Delta P_{i,t}$, the Dubai oil benchmark has the largest range between the minimum (-27.35) and the maximum (15.48). For $\Delta P_{i,t-2}$, changes in Dubai oil prices are largest, with a maximum value of 24.12, whereas the WTI has a minimum value of -46.65. In the case of $\Delta CO_{i,t}$, changes in the production of the Dubai oil regime are highest, with a maximum of 1263.627, whereas the WTI has the lowest minimum, -1701.742.

3.2 Correlation and Collinearity

It is necessary to test the correlation among the variables. If they are aggressively correlative, then there is collinearity. Thus, the results become less useful because the variables partly explain each other.

It is obvious from Table 4 that there is no collinearity problem among the explanatory variables because they are not aggressively correlated. Specifically, the correlation coefficients between $\Delta P_{i,t}$ and $\Delta P_{i,t-2}$, between $\Delta P_{i,t}$ and $\Delta CO_{i,t}$ and between $\Delta P_{i,t-2}$ and $\Delta CO_{i,t}$ are 0.3699, -0.0190 and 0.0253, respectively. Therefore, the correlation between $\Delta P_{i,t}$ and $\Delta P_{i,t-2}$ and between $\Delta P_{i,t-2}$ and $\Delta CO_{i,t}$ are positive, which means that when changes in the crude oil price volatility with a lag of two periods increase, the value of crude oil price volatility and changes in crude oil production also rise. However, the value of the correlation coefficient between $\Delta P_{i,t-2}$ and $\Delta CO_{i,t}$ is 0.0253. The positive correlation implies that as the value of crude oil price volatility with a lag of two periods increases, the value of changes in crude oil production also increases. The correlation coefficient between $\Delta P_{i,t}$ and $\Delta CO_{i,t}$ is higher, with a value of 0.3699. The correlation coefficient between $\Delta P_{i,t}$ and $\Delta CO_{i,t}$ is -0.019, indicating a negative correlation. There is also a difference in the tendency of movement between them. When changes in crude oil production increase, crude oil price volatility decreases.

Table 4   Collinearity Chart of Variables

Variables	$\Delta P_{i,t}$	$\Delta P_{i,t-2}$	$\Delta CO_{i,t}$
$\Delta P_{i,t}$	1.0000		
$\Delta P_{i,t-2}$	0.3699	1.0000	
$\Delta CO_{i,t}$	-0.0190	0.0253	1.0000

Notes: Same as Table 2.

Source: Authors' estimation based on data from EIA (2016b).

3.3. Specific Test Results

3.3.1 Panel Unit Root Test

This step applies the Levin-Lin-Chu (LLC) panel unit root test method (Andrew Levin, Chien-Fu Lin, and Chia-Shang James Chu 2002) to examine the relevant variables and determine whether they are stationary or nonstationary. Specifically, the testing hypothesis for the panel unit root test is indicated below:

H_0: Has a unit root.
H_1: Does not have a unit root.

If the results show that the *p*-value of each variable is significant, H_0 is rejected and H_1 is supported. The test results are shown in Table 5.

Table 5   Panel Unit Root Test

LLC unit root test	
Level (individual and trend)	
$\Delta P_{i,t}$	-17.84604(0.0000)***
$\Delta P_{i,t-2}$	-10.02551(0.0000)***
$\Delta CO_{i,t}$	-30.47193(0.0000)***

Notes: (1) Same as Table 2; (2) *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Source: Authors' estimation based on data from EIA (2016b).

It is apparent from Table 5 that the results are significant for all variables, indicating that H_0 is rejected and H_1 is supported. Here, the hypothesis "does not have a unit root" is accepted. This result reveals that the variables in the panel data that were contributed by cross-sectional and time-series sections are in a stationary series. Additionally, this result implies that it is possible to test for nonlinearity.

3.3.2 Linear Tests

As shown by the results of the panel unit root test, all variables are consistent with a stationary series. Therefore, it is logical to continue testing to determine whether the model reveals a nonlinear relationship between crude oil price and crude oil production.

Based on the work of Po-Chin Wu, Shiao-Yen Liu, and Sheng-Chieh Pan (2013), this paper examines the linearity testing of Equation (4) by its first-order Taylor expansion to displace the transition function $G(q_{it-d}; \gamma, c)$. Hence, the auxiliary equation showing their relationship becomes the following:

$$\Delta P_{i,t} = \alpha_i + \beta_1 \Delta P_{i,t-2} + \beta_2 \Delta CO_{i,t} + \beta'_1 \Delta P_{i,t-2} q_{t-d} + \beta'_2 \Delta CO_{i,t} q_{t-d} + \mu_{it}, \quad (5)$$

where $d = 0, 1, 2, 3, 4, 5$ to allow for a lag of two periods of crude oil price volatility. $\Delta P_{i,t}$ represents the monthly crude oil price volatility of specific oil benchmark (i) at time (t). $\Delta P_{i,t-2}$ is a lag of two periods of $\Delta P_{i,t}$. It represents the monthly crude oil price volatility of oil benchmark (i) at time $(t-2)$. $\Delta CO_{i,t}$ is the monthly crude oil production of regime (i) at time (t).

First, the hypothesis of linearity is tested to calculate the relationship between crude oil price and production and determine whether it is nonlinear or linear:

H_0: $\beta'_1 = \beta'_2 = 0$ (Linear model).
H_1: $\beta'_1 \neq \beta'_2 \neq 0$ (PSTR model with at least one threshold variable).

If the null hypothesis of linearity is rejected, the next step is to test the null hypothesis of a single threshold model against a double threshold model. Two cases are tested: one and two location parameters. The second case aims to reconfirm the results of the first test, which would imply that the results are more trustworthy. The results are in Table 6.

Table 6 Linearity Test

Test statistic	Number of location parameters (m)
	$m = 1$
Wald Test (*LM*)	2.725 (0.099)*
Fisher Test (*LMF*)	2.721 (0.099)*
LRT Test (*LRT*)	3.3 (0.099)*

Notes: *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Source: Authors' estimation based on data from EIA (2016b).

Table 6 presents the results of the Wald, Fisher, and LRT tests at a confidence level of 90%. The null hypothesis of linearity in the case of one location parameter is rejected. These estimates show clearly that the relationship between crude oil price and crude oil production is nonlinear. The principle of a minimum of the AIC or BIC reveals that the transition function fits the PSTR model.

3.3.3 The Optimal Number of Threshold Regime Tests

Due to the nonlinearity of the relationship between crude oil price and crude oil production, this paper further analyzes the optimal number of threshold variables. The hypothesis is as follows:

H_0: PSTR model with one threshold variable ($r = 1$).
H_1: PSTR model with at least two threshold variables ($r \geq 2$).

Table 7 Test of no Remaining Nonlinearities

Test statistic	Number of location parameters (m)
	$m = 1$
Wald Test (*LM*)	0.323 (0.570)
Fisher Test (*LMF*)	0.321 (0.571)
LRT Test (*LRT*)	0.323 (0.570)

Notes: Same as Table 6.

Source: Authors' estimation based on data from EIA (2016b).

According to the estimation presented in Table 7, all tests do not reject the null hypothesis for one location parameter. Therefore, the optimal number of transition functions is one.

3.4 Empirical Results

Following the above tests (panel unit root test, linearity test, and the test for the optimal number of threshold regimes), the next step is to use the PSTR model to estimate the effects of crude oil prices on crude oil production during the studied period across 122 countries worldwide. This work also presents the results of the linear model to show the differences between the PSTR model and the traditional linear model. All empirical results of the two models are presented in Table 8.

Table 8 Results of the PSTR and Linear Models

Model parameter	PSTR model	Linear panel data model
C	-	0.136624 (0.4326)
β_1	-0.0035 (0.0027)***	-
β'_1	-	-
β_2	0.0041 (0.0029)***	-
β'_2	-	-0.000281 (0.5960)
r	1.7686	-
c	-2.9332	-
N	780	780
AIC	3.1602	-
BIC	3.1841	-

Notes: Same as Table 6.

3.4.1 PSTR Model

Table 8 shows the results of the PSTR model. The threshold value c and transition parameter γ are -2.9332 and 1.7686, respectively. The explanation and implication are stated in detail as follows. In the PSTR model, the relationship between crude oil prices and crude oil production does not follow the same trend in different regimes, i.e., regimes below and regimes above the threshold value. The threshold value of crude oil volatility with a lag of two periods is -2.9332. In two extreme cases, $G\left(\Delta P_{i,t-2}; 1.7686, -2.9332\right) = 0$ and $G\left(\Delta P_{i,t-2}; 1.7686, -2.9332\right) = 1$, the effects are -0.0035 and 0.0006, respectively. Consequently, the tendency of this relationship is negative when the regime is below the threshold level but is positive when it exceeds the threshold level. The values of AIC and BIC are small enough to show that the relationship fits the PSTR model.

3.4.2 Linear Model

The purpose of this section is to present the linear model and compare its results with those of the PSTR model. In the linear model, the Durbin-Watson test statistic is 0.596032, which is not significant. Hence, the result supports the type of data that should be used in an empirical random-effects model. From Table 8, it is clear that the relationship between crude oil price and crude oil production is negative, with a coefficient of -0.000281.

Compared to the PSTR model, the linear model provides biased estimated results. Indeed, the effect of crude oil price on crude oil production is fixed at -0.000281. In contrast, as discussed above, when the PSTR model is used, the effects are based on whether the transition variable is below or above the threshold value (-2.9332). In addition, for $G\left(\Delta P_{i,t-2}; 1.7686, -2.9332\right) = 0$ and $G\left(\Delta P_{i,t-2}; 1.7686, -2.9332\right) = 1$, the effects are -0.0035 and 0.0006, respectively. Thus, unlike the PSTR model, a linear model cannot clearly reflect the relationship between crude oil price and crude oil production. With a given data set across time and countries, the PSTR model is appropriate to identify the effects of crude oil price on crude oil production using threshold points.

3.4.3 Estimation Results

As discussed in previous sections, the PSTR model surpasses the shortness of the linear model by providing more precise results. These results reveal that the relationship is nonlinear, with different effects in two extreme regimes. The threshold value c and the transition parameter γ are -2.9332 and 1.7686, respectively. The coefficient variables are β_1 -0.0035 and β_2 0.0041.

The equation that expresses the relationship between crude oil price and crude oil production can be written as follows:

$$\Delta P_{i,t} = \alpha_i - 0.0035\Delta CO_{i,t} + 0.0041\Delta CO_{i,t} \ \text{G}\left(\Delta P_{i,t-2}; \ 1.7686, -2.9332\right) + \mu_{it}, \quad (6)$$

where $\Delta P_{i,t}$ represents the monthly crude oil price volatility of specific oil benchmark (i) at time (t). $\Delta P_{i,t-2}$ is the lag of two periods of $\Delta P_{i,t}$ and represents the monthly crude oil price volatility of oil benchmark (i) at time ($t-2$). $\Delta CO_{i,t}$ is the monthly crude oil production of regime (i) at time (t).

By estimating the threshold model equation for crude oil price volatility and oil production changes, the outcome shows that there is one threshold value: -2.9332. The effects of crude oil price on crude oil production reveal differences between two circumstances, namely, regimes below and above the threshold value. In two extreme cases, $G\left(\Delta P_{i,t-2}; \ 1.7686, \ -2.9332\right) = 0$ and $G\left(\Delta P_{i,t-2}; \ 1.7686, \ -2.9332\right) = 1$, the effects are -0.0035 and 0.0006, respectively. Regarding the first case, when a lag of crude oil price volatility of two periods is less than the threshold value of -2.9332, each 1-unit increase in crude oil production volatility will lead to a 285.7-unit decrease in crude oil price volatility, showing a negative effect. It is well-known in supply-demand economics that price will decrease if supply significantly increases and other conditions are unchanged. Here, a 1-unit increase in crude oil production volatility causes a 285.7-unit decrease in crude oil price volatility only when the value of the transition variable is under the threshold point (-2.9332). In contrast, this relationship shows the opposite tendency whenever the transition variable exceeds threshold value. Specifically, when crude oil volatility with a lag of two periods is higher than the estimated threshold level of -2.9332, each 1-unit increase in crude oil production changes will cause a 1666.6-unit increase in crude oil price volatility. In summary, the effect of crude oil production on price is nonlinear, with a reversal in tendency when the transition variable is below or above the estimated threshold value.

4. Concluding Remarks

The importance of crude oil prices in the global economy has been considered in a variety of studies. However, the majority of the research focuses on the relationships among physical products and financial variables, such as the exchange rate, gold, stock prices, rig counts, interest rates, and others. Moreover, many studies argue that the impact of oil prices is consistent with oil demand and fail to consider oil production. However, a growing number of studies are researching the actual role of oil production in oil prices. In addition, a recent oversupply situation led to a significant decrease in oil prices, which raised concerns for the global economy. To reduce the unfavorable consequences of extreme oil prices caused by oversupply, OPEC members have

announced a production freeze solution. The EIA has also mentioned the importance of oil production in driving oil prices. Hence, it is important to thoroughly understand the oil price-production relationship. According to the empirical results, three implications should be noted. First, the existence of the threshold value proves the nonlinear relationship between oil price and production. Second, above the threshold value, oil production changes have a positive effect on oil price volatility. Specifically, a one-unit increase in oil production changes leads to a 1666.6-unit increase in oil price volatility. Third, under the threshold value, the effect of oil production changes on oil price volatility is negative. Specifically, a one-unit increase in oil production changes causes a 285.7-unit decrease in oil price volatility.

Thus, this study makes a contribution to both academic research and practical situations. To prevent extreme price situations, policy makers must create a strategy that predicts the trends of crude oil prices. For investors, this study is a useful reference for calculating oil price movements due to changes in oil production. For producers – especially OPEC members – this study can be used to predict oil price volatility caused by changes in oil production. Producers will thus be able to avoid oversupply situations by planning suitable levels of oil production.

References

Ahmad, Ahmad Hassan, and Ricardo Moran Hernandez. 2013. "Asymmetric Adjustment between Oil Prices and Exchange Rates: Empirical Evidence from Major Oil Producers and Consumers." *Journal of International Financial Markets, Institutions and Money*, 27(C): 306-317. http://dx.doi.org/10.1016/j.intfin.2013.10.002

Allegret, Jean-Pierre, Cécile Couharde, Dramane Coulibaly, and Valérie Mignon. 2014. "Current Accounts and Oil Price Fluctuations in Oil-Exporting Countries: The Role of Financial Development." *Journal of International Money and Finance*, 47(C): 185-201. http://dx.doi.org/10.1016/j.jimonfin.2014.06.002

Apergis, Nicholas, and James E. Payne. 2014. "Renewable Energy, Output, CO_2 Emissions, and Fossil Fuel Prices in Central America: Evidence from a Nonlinear Panel Smooth Transition Vector Error Correction Model." *Energy Economics*, 42(C): 226-232. http://dx.doi.org/10.1016/j.eneco.2014.01.003

Apergis, Nicholas, Bradley T. Ewing, and James E. Payne. 2016. "A Time Series Analysis of Oil Production, Rig Count and Crude Oil Price: Evidence from Six U.S. Oil Producing Regions." *Energy*, 97(C): 339-349. http://dx.doi.org/10.1016/j.energy.2015.12.028

Ebrahimi, Mohsen, and Nahid Cheshme Ghasabani. 2015. "Forecasting OPEC Crude Oil Production Using a Variant Multicyclic Hubbert Model." *Journal of Petroleum Science and Engineering*, 133: 818-823. http://dx.doi.org/10.1016/j.petrol.2015.04.010

Gallo, Andres, Paul Mason, Steve Shapiro, and Michael Fabritius. 2010. "What Is behind the Increase in Oil Prices? Analyzing Oil Consumption and Supply Relationship with Oil Price." *Energy*, 35(10): 4126-4141. http://dx.doi.org/10.1016/j.energy.2010.06.033

Ghassan, Hassan Belkacem, and Hassan Rafdan AlHajhoj. 2016. "Long Run Dynamic Volatilities between OPEC and Non-OPEC Crude Oil Prices." *Applied Energy*, 169: 384-394. http://dx.doi.org/10.1016/j.apenergy.2016.02.057

Ghosh, Sajal, and Kakali Kanjilal. 2016. "Co-Movement of International Crude Oil Price and Indian Stock Market: Evidences from Nonlinear Cointegration Tests." *Energy Economics*, 53(C): 111-117. http://dx.doi.org/10.1016/j.eneco.2014.11.002

González, Andrés, Timo Teräsvirta, and Dick van Dijk. 2005. "Panel Smooth Transition Regression Models." SSE/EFI Working Paper Series in Economics and Finance 604.

Güntner, Jochen H. F. 2014. "How Do Oil Producers Respond to Oil Demand Shocks?" *Energy Economics*, 44: 1-13. http://dx.doi.org/10.1016/j.eneco.2014.03.012

Hansen, Bruce E., and Byeongseon Seo. 2002. "Testing for Two-Regime Threshold Cointegration in Vector Error-Correction Models." *Journal of Econometrics*, 110(2): 293-318. http://dx.doi.org/10.1016/S0304-4076(02)00097-0

He, Yanan, Shouyang Wang, and Kin Keung Lai. 2010. "Global Economic Activity and Crude Oil Prices: A Cointegration Analysis." *Energy Economics*, 32(4): 868-876. http://dx.doi.org/10.1016/j.eneco.2009.12.005

Herrera, Ana María, Latika Gupta Lagalo, and Tatsuma Wada. 2015. "Asymmetries in the Response of Economic Activity to Oil Price Increases and Decreases?" *Journal of International Money and Finance*, 50: 108-133. http://dx.doi.org/10.1016/j.jimonfin.2014.09.004

Huang, Bwo-Nung, M. J. Hwang, and Hsiao-Ping Peng. 2005. "The Asymmetry of the Impact of Oil Price Shocks on Economic Activities: An Application of the Multivariate Threshold Model." *Energy Economics*, 27(3): 455-476. http://dx.doi.org/10.1016/j.eneco.2005.03.001

Joëts, Marc, and Valérie Mignon. 2012. "On the Link between Forward Energy Prices: A Nonlinear Panel Cointegration Approach." *Energy Economics*, 34(4): 1170-1175. http://dx.doi.org/10.1016/j.eneco.2011.10.019

Johansen, Søren. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control*, 12(2-3): 231-254. http://dx.doi.org/10.1016/0165-1889(88)90041-3

Kesicki, Fabian. 2010. "The Third Oil Price Surge - What's Different this Time?" *Energy Policy*, 38(3): 1596-1606. http://dx.doi.org/10.1016/j.enpol.2009.11.044

Kilian, Lutz. 2009. "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market." *American Economic Review*, 99(3): 1053-1069. http://dx.doi.org/10.1257/aer.99.3.1053

Kiran, Burcu. 2012. "Nonlinearity and Fractional Integration in the US Dollar/Euro Exchange Rate." *Panoeconomicus*, 59(3): 325-334. http://dx.doi.org/10.2298/pan1203325k

Kolodzeij, Marek, and Robert K. Kaufmann. 2014. "Oil Demand Shocks Reconsidered: A Cointegrated Vector Autoregression." *Energy Economics*, 41: 33-40. http://dx.doi.org/10.1016/j.eneco.2013.10.009

Levin, Andrew, Chien-Fu Lin, and Chia-Shang James Chu. 2002. "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties." *Journal of Econometrics*, 108(1): 1-24. http://dx.doi.org/10.1016/S0304-4076(01)00098-7

Linn, Robert L. 2006. "Following the Standards: Is It Time for Another Revision?" *Educational Measurement: Issue and Practice*, 25(3): 54-56. http://dx.doi.org/10.1111/j.1745-3992.2006.00070.x

Maggio, Gaetano, and Gaetano Cacciola. 2009. "A Variant of the Hubbert Curve for World Oil Production Forecasts." *Energy Policy*, 37(11): 4761-4770. http://dx.doi.org/10.1016/j.enpol.2009.06.053

Mustapha, Saidi Atanda, and Luqman Adedamola Sulaiman. 2015. "Estimating the Critical Bands for Nigeria's Crude Oil Price and Production: Evidence from GARCH Models and Interval Adjustments." *Procedia Economics and Finance*, 30: 573-585. http://dx.doi.org/10.1016/S2212-5671(15)01270-8

Natanelov, Valeri, Mohammad J. Alam, Andrew M. McKenzie, and Guido Van Huylenbroeck. 2011. "Is there Co-Movement of Agricultural Commodities Futures Prices and Crude Oil?" *Energy Policy*, 39(9): 4971-4984. http://dx.doi.org/10.1016/j.enpol.2011.06.016

Pal, Debdatta, and Subrata Kumar Mitra. 2015. "Asymmetric Impact of Crude Price on Oil Product Pricing in the United States: An Application of Multiple Threshold Nonlinear Autoregressive Distributed Lag Model." *Economic Modelling*, 51: 436-443. http://dx.doi.org/10.1016/j.econmod.2015.08.026

Park, Jungwook, and Ronald A. Ratti. 2008. "Oil Price Shocks and Stock Markets in the US and 13 European Countries." *Energy Economics*, 30(5): 2587-2608. http://dx.doi.org/10.1016/j.eneco.2008.04.003

Qin, Xiao, Chunyang Zhou, and Chongfeng Wu. 2016. "Revisiting Asymmetric Price Transmission in the US Oil-Gasoline Markets: A Multiple Threshold Error-Correction Analysis." *Economic Modelling*, 52(B): 583-591. http://dx.doi.org/10.1016/j.econmod.2015.10.003

Schubert, Stefan F., and Stephen J. Turnovsky. 2011. "The Impact of Oil Prices on an Oil-Importing Developing Economy." *Journal of Development Economics*, 94(1): 18-29. http://dx.doi.org/10.1016/j.jdeveco.2009.12.003

U.S. Energy Information Administration. 2016a. "Short-Term Energy Outlook." http://www.eia.gov/outlooks/steo/archives/dec16.pdf.

Yang, Tzu-Yi, and Yu-Tai Yang. 2015. "A Study on the Asymmetry of the News Aspect of the Stock Market: Evidence from Three Institutional Investors in the Taiwan Stock Market." *Panoeconomicus*, 62(3): 361-383. http://dx.doi.org/10.2298/pan1503361y

Wan, Jer-Yuh, and Chung-Wei Kao. 2015. "Interactions between Oil and Financial Markets - Do Conditions of Financial Stress Matter?" *Energy Economics*, 52(A): 160-175. http://dx.doi.org/10.1016/j.eneco.2015.10.003

Wang, Yudong, and Chongfeng Wu. 2013. "Are Crude Oil Spot and Futures Prices Cointegrated? Not Always!" *Economic Modelling*, 33: 641-650. http://dx.doi.org/10.1016/j.econmod.2013.05.013

Wang, Yu Shan. 2013. "Oil Price Effects on Personal Consumption Expenditures." *Energy Economics*, 36: 198-204. http://dx.doi.org/10.1016/j.eneco.2012.08.007

Wang, Yu Shan, and Yen Ling Chueh. 2013. "Dynamic Transmission Effects between the Interest Rate, the US Dollar, and Gold and Crude Oil Prices." *Economic Modelling*, 30: 792-798. http://dx.doi.org/10.1016/j.econmod.2012.09.052

Wu, Po-Chin, Shiao-Yen Liu, and Sheng-Chieh Pan. 2013. "Nonlinear Bilateral Trade Balance-Fundamentals Nexus: A Panel Smooth Transition Regression Approach." *International Review of Economics and Finance*, 27: 318-329. http://dx.doi.org/10.1016/j.iref.2012.10.010

Zhu, Hui-Ming, Su-Fang Li, and Keming Yu. 2011. "Crude Oil Shocks and Stock Markets: A Panel Threshold Cointegration Approach." *Energy Economics*, 33(5): 987-994. http://dx.doi.org/10.1016/j.eneco.2011.07.002

THIS PAGE INTENTIONALLY LEFT BLANK