A Study of the Dynamic Relationship between Crude Oil Price and the Steel Price Index[1]

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Abstract: Bulk shipping providers predominantly supply transportation services for bulk cargo, such as iron ore, grain and coal. As steel price index is a leading indicator of Baltic Dry Index, the cost of marine fuel becomes one of the key costs for shipping providers. By collecting data and building a VARMA model, this study will attempt to discover the dynamic relationship between crude oil price and the global steel price index.

The results of this study are as follows: (1) The outcomes of examining the unit root using the Phillips-Perron-test indicates that the two variables, the crude oil price and global steel price index, have a co-integration effect. This also proves that a long term balancing phenomenon exists between the crude oil price and global steel price index. (2) VARMA (3, 2) is the most suitable stage of the model for both the crude oil price and global steel price index. (3) There is a unidirectional relationship between crude oil price and the global steel price index, which means that the price of crude oil is only impacted from its own volatility. However, the global steel price index is impacted from both the movements of its own price and the volatility of crude oil price. (4) The crude oil price moves prior to movements in the global steel price index. When crude oil price increases, the global steel price index follows this upward movement. This study aims to provide a reference for investors' investment activities and shipping operators' risk aversion decisions.

JEL Classifications: C4, E3, D4, E60
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1. Introduction

Bulk shipping aims to provide transportation services for bulk cargo. Crude oil is used in the shipping process conducted by bulk shipping operators. Consequently, shipping operators may adjust the vessel's sailing speed to manage crude oil costs. During the shipping process, if vessels can be maintained at the most suitable speed, the cost of fuel can be controlled so that it is at the minimum level (Ronen, 1982). However, maintaining the most suitable sailing speed is solely for the purposes of saving fuel, rather than allowing shipping operators to understand crude oil price movements. If shipping operators are able to further understand the trend in crude oil prices and the forecast future trends, this would be greatly assist their operation planning, assets allocation and risk management (Cullinane, 1995). Therefore, this study analyzes the prior and presently used crude oil structures in order to provide useful information to shipping related operators in the areas of operation planning, assets allocation and risk management. The ultimate goal is to achieve an optimal production scale and capacity to reduce operational costs. Furthermore, this will allow management to apply price trends in reviewing the current market situation (Sempra Commodities, 2011).

Bulk shipping focuses on transporting industrial material such as iron ore, steel, grain, coal, paper pulp, and living necessities. The global economic situation is closely related to the performance of bulk shipping industry (Kavussanos, 1996). The second energy crisis during 1973-1980 results in a highly inflated crude oil price and caused the rate for bulk freight shipping to increase, resulting in turn in the increase in steel prices (Lin and Wu, 2006). Since 2000, the global demand for steel has been rising constantly. China's strong demand for infrastructure also indirectly affects the movement of steel prices (Chou and Lin, 2010). During this period, the development of emerging countries results in increased demand for steel. For instance, China's impact on the global steel demand resulted in an approximately 3-7% increase annually. In 2009, China's demand for steel resources contributed to an increased 8.6% impact on the global steel industry. Furthermore, the Olympic Games and Shanghai World Exposition held in China also resulted in substantial construction of China's domestic infrastructure, requiring an equally substantial amount of steel to support its construction projects. However, steel making requires huge amount of coal and iron ore. As a result, the demand for raw material such as iron ore and coal increased dramatically. Consequently, the global steel price soared from a minimum price of U$132.10/t as of June 5, 2009 to U$204.81/ton as of May 8, 2010. Since 2002, China has become the major driving force of global steel price increase and the primary country for steel consumption (Industrial Technology Intelligence Service, 2004).

Since 2003, the global economy recovered gradually, and China hosted the Olympic Games in 2008 and Shanghai World Exposition in 2010. To meet such strong demand from domestic construction, the demand for raw material such as iron ore also increased (Chou and Lin, 2010). However, China's domestic iron ore production remains as low grade iron ore, which is not suitable for the purpose of producing high quality steel, and from which demand from its domestic markets is high. As a result, China must partially rely on imported raw materials for producing steel (Uwe, 2004), which consequently has strengthened its demand for international bulk shipping. However, the bulk shipping industry has failed to provide sufficient vessels to transport raw material in a timely manner. As such, international freight increased rapidly, which supports the opinion of Kavussanos (1996), who believed that movements in bulk shipping freight is aligned to economic conditions. When the global economy recovers or emerging countries begin developing, in order to satisfy the domestic infrastructure demand, there will be a substantial demand for steel. Therefore, the demand for steel can be regarded as the important index to evaluate the economic conditions. The fluctuation of steel demand is reflected in the changes in steel price. In recent years, steel prices displayed an increasing volatility, which also resulted in a booming bulk shipping market (Chou and Lin, 2010). The opinions of Chou and Lin (2010) supports that of Heideloff, et al. (2006), who believed that global steel output is an essential factor affecting bulk shipping freight.

This research applies a multivariate time series model to develop a model to forecast crude oil prices and the global steel index, and investigates whether a unidirectional or bidirectional relationship exists between crude oil price and the global steel price index. Consequently, the hypothesis of this paper is: 'There exists a dynamic relationship between crude oil price and the global steel price index'. This study applies a multivariate time series model as the research methodology to determine the appropriate corresponding relationship between the variables, and to predict the future trends in crude oil prices and the steel price index. The outcomes can be used as reference points for investors who make investment and risk management decisions based on crude oil prices or the steel price index.

2. Literature Review

Crude oil price is a significant operational expense for the shipping industry. Therefore, shipping operators pay close attention to the movement in global crude oil prices and the variety and prices of oils at each refueling port. In relation to shipping operators, the process of transportation requires oil as a power source for shipping vessels. Determining the balance between sailing speed and fuel consumption is therefore not easy. The majority of vessels would rather slow down their sailing speed in order to maintain low fuel costs. However, this decision results in prolonged voyages, which increases other operational costs. As a result, Ronen (1982) suggested maintaining an optimal sailing speed during transportation to control for fuel costs and reduce operational costs. This will tremendously assist operation planning, asset allocation and risk management (Cullinane, 1995; Sempra Commodities, 2011).

The technical reports of UNCTAD (2010) indicated that crude oil price has impacts on the freight of marine container shipping. If there is an increase in the supply limit of crude oil, we can forecast a dramatic increase in crude oil prices. Additionally, the marine transportation industry is heavily dependent on crude oil supply. In particular, for emerging countries, due to the relatively higher costs of marine transportation, increases in crude oil costs have a more significant impact. These countries are naturally eager to understand how crude oil price influences marine transportation expense. Currently, global crude oil output has reached its peak, and will decline gradually. However the global demand for crude oil continues to grow (EIA, 2010). Consequently, declining output will result in price increases. Global crude oil price is highly volatile, which may affect the development of the global economy. If the risk of crude oil price volatility can be controlled, the movement in costs in the shipping market can be managed within a certain range.

The first global energy crisis took place in 1973. Since 2000, the development of emerging countries has led to increased demands on energy, resulting in a continuous rise in crude oil prices. During this period, the price increased by 2.9 times. However, the Global Financial Crisis spread worldwide, causing global economic recession, which resulted in a lower demand for crude oil. As a result, crude oil price began to fall sharply in February 2009 (EIA, 2010).

The growth in global economy and the emergence of the BRIC countries have again increased crude oil prices. This presents great challenges to the operation of large shipping companies who have large demands of crude oil. For the shipping industry, one of the most significant expenses is marine fuel (Nottelboom, 2009). In the previous five years, the huge increase in crude oil price resulted in shipping companies charging fuel surcharges to compensate for the increased costs.

The emergence of emerging countries has caused an increasing demand for steel. In particular, China's influence on global steel demand may increase 3-7% annually (Chou and Lin, 2010). For instance in 2009, China's demand for steel resources contributed to an increased 8.6% impact on the global steel industry. As China hosted the 2008 Olympic Games and 2010 Shanghai World Exposition, these infrastructure projects required substantial amounts of construction material such as steel. Furthermore, the process of steel making requires a huge amount of coal and iron ore. Therefore, there is an increasing demand for iron ore and coal. Since 2002, China became the key driving force of global steel prices (Industrial Technology Intelligence Service, 2004). In relation to coal and iron ore imports, China's market accounts for a dominating portion (BRS, 2009). As China's GDP growth reached 9% in 2003, the demands of infrastructure construction projects have become increasingly difficult to satisfy domestically, as China's own steel production is unable to meet the demand for high quality steel. Therefore, China must rely on importing more steel products to meet the demand of infrastructure construction projects (Uwe, 2004). Furthermore, due to 2008 Olympic Games and 2010 Shanghai World Exposition held in China, there is an enormous demand for iron ore and coal for infrastructure projects, which also indirectly encourages the development of the bulk shipping market. Finally, because of the influence of market demand, China became a strong force in deciding the prices of coal and iron ore (Chou and Lin, 2010). The consequent changes on policies, outputs and import and export volume resulted in global market prices movements, worsening the volatility of steel prices.

Heideloff, et al. (2006) explained in their study the main reasons which cause the steel price to influence bulk shipping freight rate. Bulk shipping freight contains a great level of uncertainty, and therefore shipping operators and investors face a significant risk. The Baltic Dry Index (BDI) is the key reference index to reflect the changes in bulk shipping freights. BDI allows bulk shipping operators and investors to assess the changes in the cost of freight in the bulk shipping market. There is a unidirectional relationship between BDI and the global steel price index, which means that BDI is the leading indicator of the global steel price index (Chou and Lin, 2010). This indicates that the increasing steel price will cause the freight index to increase. This also directly validates the viewpoints proposed by Heideloff, et al. (2006) on the relationship between the steel price and bulk shipping freight rate.

Since 2003, due to the demand for coal and iron ore, the CRU (the global steel price index) has been elevated to a volatility level between 100 points and 200 points, instead of the previous level of around 100 points (BRS, 2009). This phenomenon indicates that, in steel market, the steel price has been increased to another peak due to the growth of the Chinese economy. According to the outcomes of the literature review, Bin (2007) analyzed the relationship between China's steel price and the global steel price. Yau, et al. (2006) studied the impact of the Chinese steel price on Taiwan's steel price and discovered a balancing relationship between the two (Liu and Wu, 2006). Furthermore, the global steel price is a leading indicator of the Baltic Dry Index (Chou and Lin, 2010), and therefore has an influence on freight (Chou and Hurang, 2010). As a result, we find that the impact of crude oil prices and the global steel price index on the economy is closely related to the shipping industry (Heideloff, et al., 2006). In relation to the studies on crude oil price, the majority of the extant research focused on the economic or financial aspects, whilst few concentrated on the relationship between the crude oil price and bulk shipping operators. However, marine transportation is heavily dependent on the supply of crude oil, and crude oil costs account for a significant portion of operational costs. In addition, the price of crude oil is easily affected by international situations, such as production reductions by oil-producing nations, political factors or exchange rate volatility. The global steel price index is regarded as an essential index for bulk shipping operators (Heideloff, et al., 2006) as the steel price index affects the Baltic Dry Index, which is considered a leading index (Chou and Lin, 2010). As a result, the crude oil price and global steel index are important for shipping operators. Therefore, our study will analyze the relationship between crude oil price and the global steel price index.

The multivariate time series model is the most suitable model to forecast crude oil price series and global steel price index series, and can directly illustrate the relationship between variables from the data collected. Using the forecasting model, we can discover the relationship between crude oil price and the global steel price index to abstract the trends for crude oil prices or the global steel price index for the purpose of providing a reference for decision making by shipping operators or investors.

3. Methodology

For econometric analysis tools, the analysis of time series plays a significant role (Hansen and West, 2002) (Hamilton, 1994). Vector Autoregressive Moving Average (VARMA) has been applied in a significant number of literatures (Chou and Hurang, 2010; Chou and Lin, 2010); Chou, 2011). Our research employs the VARMA model to construct a dynamic model between crude oil price (OIL) and the global steel price index (CRU) to conduct the analysis. Since the main purpose is to understand the relationship between various variables in the system, this model can address the shortcomings of the univariate time series, and can analyze whether a feedback relationship exists amongst the series (Hamilton, 1994). VARMA is able to collect more knowledge on this relationship and collectively develop models which can obtain information from a related series, thereby effectively constructing a dynamic relationship among the variables and improve forecasting accuracy.

We assume OIL and CRU series as a stationary series. If the VARMA model is VARMA (1, 1), then $\phi(B)Z_t = C + \theta(B)a_t$ can be simplified as:

$I - \phi(B)Z_t = (I - \theta B)a_t$, of which a formula of matrix and vectors is as follows:

$$\left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} B\right) \begin{bmatrix} OIL_{1t} \\ CRU_{2t} \end{bmatrix} = \left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} \theta_{11} & \theta_{12} \\ \theta_{21} & \theta_{22} \end{bmatrix} B\right) \begin{bmatrix} a_{1t} \\ a_{2t} \end{bmatrix}$$

In this formula, $\phi(B) = 1 - \phi_1 B - \cdots - \phi_p B^p$, $\theta(B) = 1 - \theta_1 B - \cdots - \phi_p B^p$ is a matrix polynomial of B , ϕ and θ are a k × k matrix, ***c*** is k × 1 fixed value vector, a_t is random vibration vector of a series of independent normal distribution with zero average value. The covariance matrix is $\sum$ and the constant vector C is regarded as constant C , which can be demonstrated as C = $\left(I - \phi_1 - \phi_2 - \cdots - \phi_p\right)\mu$, parameters ϕ_{ij} and θ_{ij} can be illustrated as the manner in which series i is affected by series j .

Macroeconomic variables are predominately non-stationary series (Nelson and Plosser, 1982), and the series analyzed in this paper is also a macroeconomic variable. Therefore, prior to estimation using the VARMA model, we must first conduct a unit root test for each variable, and confirm that both the crude oil price and global steel price index can pass the process of unit root test and are stationary series. Once the series are confirmed to pass the unit root test, we can then examine the causal relationship of the two sets of series; otherwise, we only can test whether a Co-integration effect exists between the two variables (Engle and Granger, 1987). The co-integration effect illustrates that the regression relationship between non- stationary variables may a cause false causal relationship, and therefore the conclusions may be made incorrectly. If crude oil price series and global steel price index series are non-stationary, we must convert them into a stationary series. If the original series appears stationary after *p* times of finite difference, we then can call this series a Co-integration with *p* steps, which can be marked as *I(p)*. Consequently, after a *p (p>0)* steps co-integrating the non-stationary variables, crude oil price and global steel price index, we can refer to crude oil price series and global steel price index series as *p* steps *p* times co-integration, with a symbol *CI(p, p)*.

Once crude oil price series and global steel price index series can be showed as stationary, we can then conduct analysis on their causal relationship. The order of VARMA model for crude oil price series and global steel price series can be measured as the best candidate model through SCAN (the smallest canonical), which is derived from Partial Autoregression (PAR). The SCAN method provides an easier method of deciding the most suitable candidate model than PAR (Liu et al. (1992-1994)) (Liu et al. (1997-2002)). As a result, this paper applies SCAN to test the suitable steps of VARMA, and to seek necessary information.

4. The Empirical Analysis of Crude Oil Price and Global Steel Price Index

Market supply and demand determines the price of crude oil. In relation to demand, international economic growth is the greatest factor, as economic development relies on energy, and crude oil accounts for 35% of global energy consumption. The crude oil price series applied in this paper is sourced from U.S. Energy Information Administration, EIA), published in 2010. Figure 1 is the trend of crude oil price during June 2000 to July 2010.

Figure 1 The trend of crude oil price during June 2000 to July 2010

The outbreak of the Gulf War in 2000 resulted in an increased crude oil price. Later, the development of emerging countries such as China and India strengthened the demand for energy. Following the violence between Israel and Palestine in September 2000, the situation in Middle East worsened rapidly. All these have led to the increase in crude oil prices, increasing gradually and continually. However, continuous increases in international crude oil price are mainly due to increased global demand for crude oil, and these factors fuelled the soaring of crude oil price, which also has a significant impact on the global economy. As a result, the US government announced a supply of 30 million barrels of strategic petroleum reserve to meet the demand. In August 2005, the crude oil drilling facilities in Mexico gulf were seriously damaged by Hurricane Katrina, which resulted in the international crude oil price reaching its peak. Since the beginning of 2006, due to multiple occurrences of damage to oil drilling facilities in Nigeria, oil production from oil drilling platform experienced a serious shortage. Consequently, the capacity of crude oil had been limited. In addition, with the intense political atmosphere in Iran, crude oil supply continues to be subject to increasing uncertainty. Due to the uncertain supply, limited production capacity, the supply of crude oil remains tight. As a result, crude oil prices continue to soar. In August 2006, the largest oil field in the US, the Alaska North Slope Oil Field, closed operations following a ruptured pipeline accident and oil spill. This incident resulted in a sharp production decline of 8% in the US. Although its government was able to resolve supply tension through importing, this event has increased the burden on international oil supply, and caused oil price spikes. For instance, in section I of Figure 1, it is clear that from June 2, 2000 to March 23, 2007, the lowest price of crude oil was US$16.5100/barrel, and the highest price was US$72.1000/barrel, with a mean price of US$36.5134/barrel.

The military conflict between western countries and Iraq in 2007, stimulated the soaring of crude oil price. Consequently, the political factors in Middle East region may cause the volatility of crude oil price. Since 2007, alongside the recovery of the global economy, crude oil price began increasing rapidly, and increased 2.2 times during this period. Since August 2007, the international crude oil price has started to soar continually. The main explanation was the influence from the subprime mortgage crisis, which impacted international crude oil price in two aspects: firstly, The US Federal Reserve announced several interest cuts in order to control for the sub-prime mortgage crisis. This decision resulted in the US dollar depreciating dramatically caused by the retreat of foreign investment from the US market, which previously offered high interest rates. The consequence of this reaction was the rapid increase in crude oil price, with hedge funds entering into crude oil markets to avoid the risk from the sub-prime mortgage crisis, with this change increasing oil price even further. For instance, as can be seen in section II of Figure 1, between March 30, 2007 and August 29, 2008, the lowest crude oil price was U$61.7000/barrel, and the highest was U$137.1800/barrel, with a mean price of U$90.8753/barrel.

As of June 2008, the US experienced a worsened unemployment rate and slow economic growth, which increased crude oil prices to a record high. Additionally, political unease in the Middle East region increased the volatility range of the crude oil price. As a result, the U.S. Energy Information Administration and International Energy Agency downgraded the forecast of crude oil demand. Later, in September 2008, with the accidents from the Mexico Gulf oil drilling platform triggered by the Atlantic hurricanes caused the production of refinery plants dropped again. Shortly after, Lehman Brothers filed for bankruptcy and Merrill Lynch was offered for sale. The Global financial crisis occurred due to the impact of the American sub-prime mortgage crisis in December 2008, with the global economy and international trade declining simultaneously, which resulted in a global decline in demand for crude oil. Consequently, the crude oil price dropped from U$137.1800/barrel in July 2008 to U$37.7200/barrel by the end of 2008. However, due to the recovery of the global economy, crude oil price started increasing in 2009, as can be seen in section III of Figure 1, during September 5, 2008 and March 8, 2009, the crude oil price reached the lowest level of U$35.4800/barrel, and the highest level at U$106.39/barrel, with the mean price as U$66.2597/barrel.

Afterwards, alongside the further recovery of the global economy, the demand for crude oil also increased. Crude oil prices started moving upwards slowly since 2009. In section IV of Figure 1, between May 15, 2009 and July 30, 2010, crude oil price reached the lowest level as of U$55.7100/barrel, and highest level as of U$84.2800/barrel, with the mean price being U$72.5975/barrel. Our research applies the crude oil price series from June 2, 2000 to July 30, 2010, where the lowest level was U$16.51/barrel, and the highest level was U$137.18/barrel, with the average price being U$49.81/barrel.

The global steel price index is also decided by the market demand and supply. When demand exceeds supply, global steel price index is set to rise, which also encourages steel makers to stock up on steel making raw material to produce steel. The global steel price index employed in our research is published by CRU. Figure 2 is the trend of global steel price index during June 2000 to July 2010.

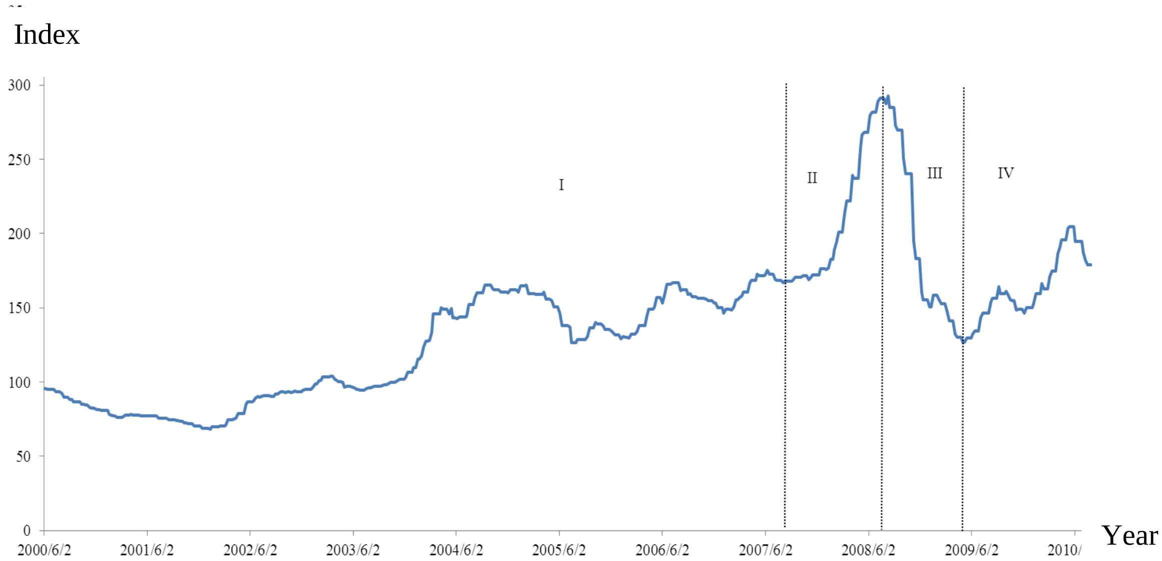

Figure 2 The trend of global steel price index during June 2000 to July 2010

Since 2003, the rapid rise of developing countries such as China and India, in particular, drove a strong demand for iron ore and raw material to meet the demand from their domestic infrastructure. The production capacity of Chinese steel plants has been increased quickly, which creates an increasing demand for bulk commodities. Therefore, China purchased a vast amount of commodities from other countries, and China's import of iron ore was also increased due to the fast growth of steel production. As of the beginning of 2006, China increased the portion of domestic iron ore supply in order to gain new annual iron ore import contracts and strengthen its negotiation power with foreign iron ore producers. This decision resulted in China slowing down iron ore importation. The new iron ore contract prices were confirmed to increase, and therefore global steel plants lifted iron ore shipping volume prior to the expiry of their previous contracts, which caused an increase in the global steel price. For example, in sector I of Chart 2, between June 2, 2000 and February 2, 2007, the global steel price reached the lowest level of U$68.50/ton, and the highest level of U$166.67/ton, with an average of U$115.04/ton.

Once the iron ore prices were increased in 2007, an overstocking effect appeared in the first quarter. Many Chinese iron ore importers attempted to import a vast amount of iron ore before April 1, which worsened port congestion in Australia and Brazil. In addition, India started charging iron ore export duty and caused iron ore stock deficiency in Chinese steel plants. All of these factors triggered the increased in the global steel price index. The 2008 The Olympic Games held in China also required a substantial amount of steel construction material in order to meet the demand of infrastructure. However, China was unable to produce sufficient amount of steel to meet the market demand for high quality steel. Therefore, China must partially rely on importing steel (Uwe, 2004). As a result, the global steel price index increased rapidly during this period. In section II of Figure 2, between February 9, 2007 and August 29, 2008, global steel price reached the lowest level at U$150.84/ton, and the highest level at U$292.78/ton, with the average price as U$201.26/ton.

After 2008, the financial shocks from the global financial crisis spread worldwide, causing a global economic recession. Consequently, the demand for steel dropped accordingly. Global steel price index started declining in September 2008. The collapse of Lehman Brothers and the subprime mortgage crisis in the US at the end of 2008 worsened the impact of the financial crisis. As a result, global steel demand was declining and caused a rapid decline in the global steel price index during this period. For instance, in section III of Figure 2, the global steel price reached the lowest level at U$126.51/ton, and the highest level at U$272.88/ton, with an average of U$174.11/ton, during September 5, 2008 and May 29, 2009.

As of June 2009, the recovery of global economy increased the demand for steel. Additionally, emerging regions, such as China, were on track for rapid economic growth. Furthermore, the 2010 Shanghai World Exposition held in China also strengthened the demand for steel products. As a result, global steel price started increasing. In section IV of Figure 2, between June 5, 2009 and July 30, 2010, global steel price reached its lowest level at U$132.10/ton, and highest level at U$204.81/ton, with an average price of U$165.6305/ton. Our research employed the global steel price index series from June 2, 2000 to July 30, 2010, with the lowest price as U$68.50/ton and the highest price as U$292.78/ton, with an average price of U$138.50/ton.

This study is to establish the correlation between the structures of crude oil and steel price indices. The data series employed is $Z_{1t}(Oil)$, which represents crude oil price, and data series two is $Z_{2t}(CRU)$, which represents the global steel price index. This study assumes the relationship between crude oil price and global steel price as follows, and the final outcomes can be determined through the extended VARMA model.

Due to the existence of unit root in macroeconomic index variables (Nelson and Plosser, 1982), from Figures 1 and 2, we can roughly determine the existence of the variable's intercept or trend. Therefore, our research first conducts stationary tests on the crude oil price index series and global steel price index series to determine whether the two series are stationary. There are 531 weekly data sets for each crude oil price series and global steel price index series employed by our research. We maintained 15 sets for RMSPE model stimulation, and applied the Phillips-Perron-test[2] to examine whether the series appears stationary. The null hypothesis of the test is that the crude oil price and global steel price index series are non-stationary. Prior to testing the data, our study first found the natural logarithm of the original series and conducted stationary analysis. The test results are listed in the tables below. Table 1 indicates those with a significant level below 5%, which is insignificant. This means the both series are non-stationary, which means that the data series have unit root effect, and crude oil price series and global steel price index are both non-stationary series. Therefore, we conducted a difference test for both OIL series and CRU series, before applying the Phillips-Perron-test. The results in Table 2 demonstrate the data series appear to be stationary after both OIL series and CRU series. We can then refer to OIL and CRU series as CI (1, 1). Therefore, the two economic variables, OIL series and CRU series, have a long term balancing relationship.

[2] Phillips-Perron test allows testing for the autocorrelation and heteroscedasticity of residue of the test model. The Phillips-Perron test still applies the distribution of Dickey-Fuller test, only with a different hypothesis. The Phillips-Perron test (PP), Augmented Dickey-Fuller (ADF), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) can be found in EViews.

Table 1 Phillips-Perron-test with Constant

Variable	t with Constant[3]	t with trend
CRU	-1.71	-2.72*[4]
OIL	-1.61	-2.79*

Table 2 The Unit Root Test after First-order difference

Variable	t with Constant	t with trend
CRU	-21.83***	-21.82***
OIL	-18.02***	-18.01***

Our study mainly constructs a multivariate time series model for both the crude oil price series and global steel price index series, and employs SCAN charts to determine and compare the orders of time series model VARMA (*p*, *q*). Therefore, after determining the best order of VARMA (*p*, *q*) through the charts of SCAN(Figure 3), the possible orders of VARMA include VARMA(2, 4), VARMA(3, 2), VARMA(5, 1) and VARMA(6, 0); these are our four candidate models.

Q	0	1	2	3	4	5	6
0:	X	X	X	X	X	X	X
1:	X	0	X	X	X	0	X
2:	0	0	0	X	0	0	0
3:	X	0	0	0	0	0	0
4:	X	X	0	0	0	0	0
5:	X	0	0	0	0	0	0
6:	0	0	0	0	0	0	0

Figure 3 The SCAN of CRU and OIL at 1% Significant Level

Our study retains 15 sets of data for the purpose of external forecast, and determines the forecast quality of four candidate models using RMSPE. We compared stimulated forecasts and actual index value, using RMSPE to estimate. By using the OIL series to forecast CRU series, its values are 2.1752%, 1.2656%, 2.9399% and 2.9146% (Table 4). Smaller RMSPE estimation represents better forecast quality, and therefore, in relation to estimation results, the RMSPE value of VARMA(3, 2) is the smallest, with 1.2656%, as a result, and this has the best forecast quality. In addition, when using the CRU series to forecast OIL series, the RMSPE values are 3.5103%, 2.9506%, 4.2925%, and 4.2795% respectively (Table 5). The smallest value occurred in VARMA(3, 2), and therefore, VARMA(3, 2) is the most suitable model when using the CRU series to forecast OIL series.

Table 4 RMSPE Estimation Results of Forecast CRU via OIL

Model	VARMA(2, 4)	VARMA(3, 2)	VARMA(5, 1)	VARMA(6, 0)
RMSPE	2.1752%	1.2656%	2.9399%	2.9146%

[3] The significant levels of PP test at 1%, 5%, 10% are -3.44, -2.87 and -2.57.

[4] The significant levels of PP test of 1%, 5%, 10% are marked as ***,** and *, respectively; both in tables 1 and 2.

Table 5 RMSPE Estimation Results of Forecast OIL via CRU

Model	VARMA(2, 4)	VARMA(3, 2)	VARMA(5, 1)	VARMA(6, 0)
RMSPE	3.5103%	2.9506%	4.2925%	4.2795%

After the tests stated above, we find that the most suitable order of VARMA is (3, 2) when forecasting CRU using OIL, with the best model orders both being VARMA (3, 2). Hence, we list the matrix-style formula and the extended list of the combined matrix of the coefficient values and parameters of VARMA (3, 2), and also the expanded formula that determines the values' correlation values and parameters of VARMA (3, 2):

$$\begin{bmatrix} OIL_t \\ CRU_t \end{bmatrix} = \begin{bmatrix} 0.11 \\ (0.04) \\ -0.04 \\ (0.06) \end{bmatrix} + \begin{bmatrix} . & . \\ & \\ . & 0.60 \\ & (0.25) \end{bmatrix} \begin{bmatrix} OIL_{t-1} \\ CRU_{t-1} \end{bmatrix} + \begin{bmatrix} 0.47 & . \\ (0.19) & \\ . & 0.61 \\ & (0.22) \end{bmatrix} \begin{bmatrix} OIL_{t-2} \\ CRU_{t-2} \end{bmatrix} + \begin{bmatrix} . & . \\ & \\ -0.96 & \\ (0.44) & . \end{bmatrix} \begin{bmatrix} OIL_{t-3} \\ CRU_{t-3} \end{bmatrix} +$$

$$\begin{bmatrix} a_{OIL_t} \\ a_{CRU_t} \end{bmatrix} - \begin{bmatrix} -0.99 & . \\ (0.20) & \\ . & -0.62 \\ & (0.25) \end{bmatrix} \begin{bmatrix} a_{OIL_{t-1}} \\ a_{CRU_{t-1}} \end{bmatrix} - \begin{bmatrix} -0.48 & . \\ (0.15) & \\ . & . \\ & \end{bmatrix} \begin{bmatrix} a_{OIL_{t-2}} \\ a_{CRU_{t-2}} \end{bmatrix}$$

$$OIL_t = 0.11 + 0.47 OIL_{t-2} + a_{OIL_t} + 0.99 a_{OIL_{t-1}} + 0.48 a_{OIL_{t-2}}$$

$$CRU_t = -0.04 + 0.60 CRU_{t-1} + 0.61 CRU_{t-2} - 0.96 OIL_{t-3} + a_{CRU_t} + 0.62 a_{CRU_{t-1}}$$

From the structural formula above, we found that OIL is affected by its historical two week price, although it is not affected by CRU. CRU is impacted from both historical one week and two week CRU indices, as well as the historical three week OIL (Crude oil price) indices.

The outcomes of the empirical analysis of the crude oil price series and global steel price index series in this study are listed as follows:

1. It is confirmed that CRU (Global steel price index) is impacted by OIL (Crude oil price);

2. CRU series and OIL series belong to CI (1, 1) series type;

3. Crude oil price is impacted by its historical two weeks price, and is not influenced by the global steel price index. The global steel price index is affected by both historical one week and two week global steel prices, as well as the historical three week crude oil price. These findings suggest that the crude oil price will be only affected by its own volatility, and the global steel price index will be impacted from the volatilities of its own and the crude oil price.

5. Conclusions

This research mainly applies the crude oil price series and global steel price index series as the analytical subjects, and collects data sources from the EIA and CRU database respectively, including 531 sets of weekly data. We then conducted a VARMA model building and stationary analysis, and determined the two variables belong to CI (1, 1) series type through the results of the Phillips-Perron-test. This suggests that the unit root testing results of the Phillips-Perron-test indicates a long term balancing effect between the two variables of crude oil price and the global steel price index.

The main contributions of our study include the outcomes of Phillips-Perron-test and VARMA model, indicating there is a co-integration effect between crude oil price and global steel price index. This also suggests the existence of a long term balancing effect between the crude oil price and global steel price index. The results of the VARMA model indicate that: (1) A unidirectional relationship exists between the crude oil price and the global steel price index, which means that crude oil price is only be affected by its own price movement. On the other hand, the global steel price index is affected by both its own index movements and crude oil price volatility. (2) Crude oil price moves prior to the global steel price index, which means increases in crude oil price will increase the global steel price index.

In relation to shipping operators, the two data series of crude oil price series and global steel price index series are regarded as two essential indices. The crude oil price is one of the main costs for shipping operation (Sempra Commodities, 2011; UNCTAD, 2010), and global steel price index is also an essential index for bulk shipping operators (Heideloff, et al., 2006) as the steel price index will affect the Baltic Dry Index. As a result, the steel price index is a leading index (Chou and Lin, 2010). Therefore, the findings of our research are able to provide more information to the shipping operators for the reference in investment or risk management.

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