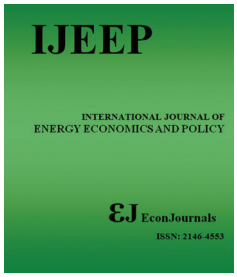

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The Relationship between Crude Oil and Coal Markets: A New Approach

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ABSTRACT

The level of substitutability of crude oil and coal in production and consumption may lead to the relationship between them. In this paper, the relationships between crude oil market and coal market are investigated, using a structural vector autoregressive model (SVAR). We apply the Kilian (2009) index to distinguish between the effects of oil market demand shocks and global aggregate demand shocks. The empirical results suggest that coal prices are affected by the supply and demand shocks of the oil market, while oil supply shocks have no effect on oil prices. This shows a high level of interaction between the crude oil market and the coal market, arising mainly due to the role of substitution. The effect of global aggregate demand on the price of coal is higher than the effect on the price of oil. Meanwhile, the fear of future oil supply affects the coal market only temporarily.

Keywords: Crude Oil Price, Coal Price, Oil Supply Shock
JEL Classifications: Q41, Q43

1. INTRODUCTION

Coal and oil are the two most important sources of primary energy in the world. In fact, the first fuel that household began to burn for heat was coal and after that coal has been used as a fuel for thousands of years. As nations became industrialized, coal allowed the rapid growth of factories. After the discovery of oil, the use of coal was overtaken by the use of oil. Coal fueled steam engines in trains long before the advent of the liquid-fuel-powered engines of today. The main factors that cause countries replace oil with coal in some sectors were environmental pollution and transportation. Coal has caused substantial air pollution as well as ground and surface water pollution due to its mining, transportation, and consumption. Pollution from coal is much higher than that from oil. Coal is a steady supplier of greenhouse gases that cause many countries to attempt to restrict its consumption in the world. For example, before the second oil shock, the United States and some other countries had established rules creating a coal-production ceiling, although they had to remove these rules gradually after the second oil shock to compensate for the decline in oil production.

Transportation is the second issue causing countries to try to replace coal with oil after the discovery of oil. About 25% of coal is traded internationally which most of this amount is traded via ships and requiring access to maritime waterways. A large share of the total delivered price of coal is transportation cost. For these reasons, coal markets often have a domestic or regional orientation, while oil has a global market. Although, with progress in technology and improving transportation for coal, the small, segmented, and domestic coal markets have moved toward a global market. For example, increasing seaborne trade for coal has unified segmented coal markets into a global market (e.g., Ellerman [1996]).

Consequently, environmental pollution and transportation are two main issues that have caused consumers to replace coal with oil. However, during the last centuries, the amount of oil available in some periods has declined suddenly, producing high interactions between oil and coal production and consumption. After the oil price shock of 1973, electric utilities saw a need to reduce their reliance on petroleum. Most of the new utility plants built after 1975 were coal and nuclear facilities. As a result, a large portion of the oil-fired capacity in the late 1970s and early 1980s was reserved for peak load periods or for emergencies and routine maintenance periods. Due to new plant construction and higher oil prices in the late 1970s and early 1980s, the use of

residual fuel oil at electric utilities declined substantially. From a peak oil consumption of 1.7 million barrels per day in 1978, oil consumption at electric utilities fell to 475,000 barrels per day in 1985. In this period, the production of coal began to increase. In the late 19th century by increasing its use in the generation of electricity, coal became a mainstay in electric power plants. Therefore, the use of coal shifted primarily to the generation of electricity, while oil and natural gas competed in several residential and commercial end user markets.

As a result, a high level of substitutability between coal and oil began many years ago that may lead to relationships between them.

For coal, factors such as alternative fossil fuel markets, changes in environmental laws, changes in weather, labor issues, and technological innovations impact pricing volatility. In the last decade, because of high regulatory restrictions and reserve depletion that led to significant supply inelasticity and increased price volatility, coal prices have changed substantially. Coal prices suddenly increased by 40% in 2001 in comparison with 2000 and by 300% in 2008 in comparison with 2006.

The factors that cause volatility in oil prices are similar to those that cause volatility in coal markets. However, in the oil market, cartels such as the Organization of the Petroleum Exporting Countries (OPEC) and oil exporter countries as members of oil cartels have the power to change oil prices by changing their policies.

Meanwhile, policy also plays an important role in the coal market, but more weakly than in the crude oil market. After the first and second oil shocks that originated in the Middle East, policymakers began to change their policies about coal. Many policymakers decided to shift energy usage toward greater coal consumption. Coal in some countries, such as the United States and South Africa, is a domestic energy resource. Therefore, by increasing the consumption of coal and decreasing the share of crude oil in the energy supply basket of countries, these countries could decrease their dependence on the oil market. They shifted their share of crude oil to the coal market by prohibiting the use of oil and natural gas in electric utilities that could use coal. In 1975, policymakers extended this rule for 2 years. Furthermore, they attempted to increase coal production to offset the decline in crude oil availability via loans for new coal mines.

Another policy that helped shift crude oil market share towards the coal market was removing the production ceiling of coal.

Since 1985, coal has not been subjected to explicit regulations. However, as the high pollution rates of coal countries required the establishment of new regulations for the coal market, these regulations were mainly about coal consumption, rather than coal production.

Some researchers have studied the long-run and short-run relationships between the crude oil and coal markets. Zellou and Cuddington (2012) studied trends and super cycles in crude oil and coal prices. They identified four apparent super cycles in coal prices over the period 1800 to 2009 and three super cycles in oil prices over the period 1861-2010. These coal super cycles roughly matched the timing of those for oil and metal prices after World War II, but not those in the pre-World War II period.

Li et al. (2010) investigated the long-run relationship between international steam coal prices According to their cointegration tests results; they found some evidence that the international steam coal market in generally integrated. Some researchers found evidence that "the world oil market, like the ocean, is one great pool," (Adelman [1984]). Some studies investigated the short-run and long-run relationships between crude oil, coal, and natural gas.

In this paper, we investigate the structural relationships between coal and oil markets to understand how the coal market affects the oil market and its prices in the short-run.

The rest of the paper is organized as follows. In the next section, we first describe the data. Then, in the second subsection, we explain our model and show our empirical results. Our interpretations are explained in next subsection. In the third section, we conclude our results.

2. EMPRICAL ANALYSIS AND RESULTS

2.1. Data

Our dataset includes monthly data from January 1989 to December 2013 and consists of four variables: The percent change in global crude oil production, the new index of real economic activity (Kilian's index), the real price of oil, and the real price of coal.

The percent change in global crude oil production is the log differences from the U.S. Energy Information Administration (EIA) of average monthly crude oil production in millions of barrels pumped per day. The index of real economic activity is the monthly index of global real economic activity based on dry cargo bulk freight rates, as demonstrated by Kilian (2009). The real oil price is the monthly imported crude oil price of the United States and is obtained from the EIA. The real coal price is the monthly Australian coal price, as the biggest exporter coal country from the World Bank Cross Country Data in dollars per million ton. The prices of oil and coal are expressed in log units and have been deflated by the U.S. consumer price index.

According to the EIA, Indonesia was the biggest coal exporter country in 2012 and Australia was second, while the amount of coking coal export of Indonesia is negligible in comparison with this amount for Australia.

On the other hand, for many years, the total amount of Australia's coal exports was bigger than those of Indonesia and it was just in 2012 that Indonesia gained first place. In early 2011, Australian coal-producing regions were affected greatly by Australia's typhoon season and recovery from extensive damage to their infrastructures took months. This led to a decrease in the volume of production and export. For these reasons, we chose Australia's coal price as the price of the world coal market, as it was the biggest coal exporter country in our period.

2.2. Model

To investigate the relationship between crude oil and coal, we applied a four-variable SVAR model. Our dataset consisted of four variables: The percent change in global crude oil production, $\Delta prod_t$; the new index of real economic activity (Kilian's index), rea_t; the real price of oil, rpo_t; and the real price of coal, rpc_t.

$$z_t = (\Delta prod_t, rea_t, rpo_t, rpc_t) \quad (1)$$

The model in its SVAR representation is written as,

$$A_0 z_t = \alpha + \sum_{i=1}^{p} A_i z_{t-i} + \varepsilon_t \quad (2)$$

Where ε_t is the vector of serially and mutually uncorrelated structural errors. We postulate a recursive structure for our model, A_0^{-1}, such that the reduced form errors e_t can be written according to $e_t = A_0^{-1} \varepsilon_t$:

$$e_t = \begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{rpo} \\ e_t^{rpc} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{oil supply shock}} \\ \varepsilon_t^{\text{aggregate demand shock}} \\ \varepsilon_t^{\text{oil specific-demand shock}} \\ \varepsilon_t^{\text{coal price shock}} \end{pmatrix} \quad (3)$$

In this model, we have six restrictions. The first five restrictions are based on assumptions made by Kilian in his model (2009). The unpredictable innovations of global crude oil production are defined as oil supply shocks. The first three restrictions are based on this assumption. The fourth and fifth restrictions are assumed innovations to the global real economic activity and are explained based on the oil supply shocks and aggregate demand shocks. Oil-specific demand shocks reflect fluctuations that arise from fear about future oil supply shortfalls. Our last restriction is explained as innovations to the real price of oil as based on oil supply shocks, aggregate demand shocks, and oil-specific demand shocks.

The last restriction explains innovations to the coal price based on all of our shocks, consisting of oil supply shocks, aggregate demand shocks, oil-specific demand shocks, and coal price shocks.

As we mentioned before, the coal market has small and segmented markets (Zellou and Cuddington [2012]) that, as technology progresses, have slowly moved toward a global market in recent years. The oil market, on the other hand, has main cartels, the most important one, OPEC, controls the amount of crude oil supply to control the price of crude oil. The power of these cartels leads to a highly integrated economic market for crude oil (Bachmeier and Griffin [2006]). As a result, the oil market is more powerful than the coal market, and we assume that the oil market can affect the coal market as a substitute fossil fuel.

2.3. Empirical Results

We generated impulse responses of oil supply shock, aggregate demand shock, oil-specific demand shock, and coal price shock on oil production, real activity, the real price of oil, and the real price of coal. All of our shocks were normalized. The error of reduced-form VAR of the model was based on a recursive-design wild bootstrap with 2000 replications (Goncalves and Kilian [2004]). The reduced-form VAR model was estimated by the least-squares method. The results are shown in Figure 1.

In response to oil supply shock, the global oil production decreased significantly to a lower amount. As oil is a critical fuel, countries attempted to increase their production in order to compensate for this decline in the global oil production. Therefore, the production of oil slightly increased, but remained in an amount less than the primary amount. Figure 1 shows that oil supply shock had no significant effect on the real activity and real price of oil, but it had a statistically significant effect on the real price of coal for approximately 7 months.

The main cause of oil supply shock's significant effect on coal prices is substitutability, in which an increase in the price of one good because of supply shortfalls or increasing demand results in an increase in demand for its substitute goods. However, in our results, crude oil supply shock had no significant effect on crude oil prices, while it had a positive effect on coal prices.

This illustrates that, on the back of oil production, there is a power that reflects the effect of oil supply decline to the coal market. This power is policy. Policymakers attempt to compensate for oil supply declines by increasing coal demand. This happened especially after the first and second oil shocks. After these shocks, countries decided to compensate for the sudden oil supply shortfalls by shifting the demand for crude oil toward a demand for coal.

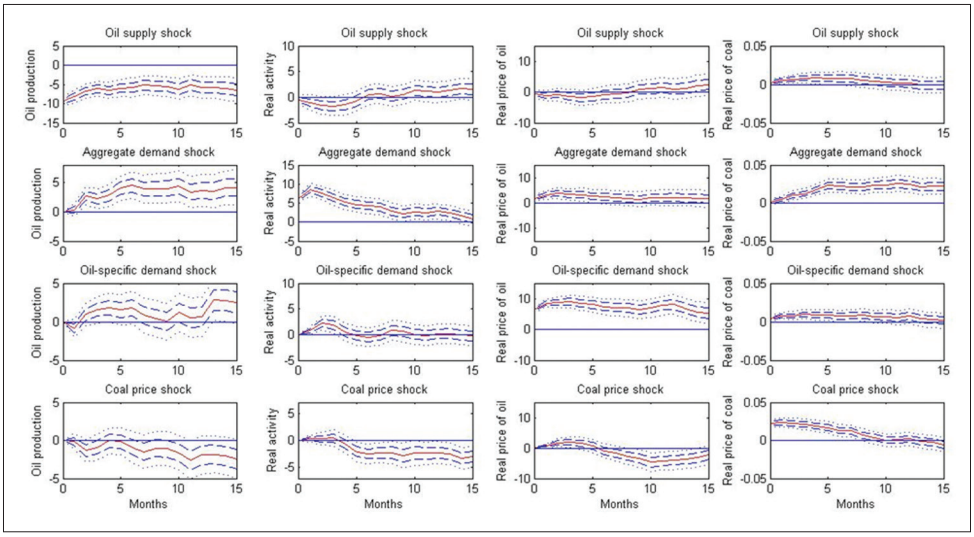
This still leaves the question regarding the effects of aggregate demand shock on oil production, oil prices, and coal prices. Figure 1 illustrates that an unanticipated aggregate demand increase had a positive and significant effect on real activity.

The results show that a positive aggregate demand shock had a positive and significant effect on the prices of oil and coal. When global demands for industrial goods increased, there was an increased demand for energy. This mainly led to an increase in the demand for crude oil as the main fuel in transportation and coal as the main fuel in generating electricity.

Figure 1 demonstrates that oil production rapidly increased to higher amounts in response to the global aggregate demand shocks, and this rise continued until around 7 months, then remained approximately on the same level until the end of our horizon. This result is similar to previous results in Zamani (2016) in that an unanticipated aggregate demand increase had a positive and significant effect on the production of oil. These results are different from those shown by Kilian (2009). He found some evidence that global aggregate demand shock had no significant effect on oil production. However, our results of the effects of aggregate demand shock on oil prices were similar to those of Kilian (2009).

In response to the oil-specific demand shock, the results illustrate that a positive oil-specific demand shock caused an increase in the prices of both crude oil and coal. An unanticipated increase

Figure 1: Impulse responses of structural shocks



in oil-specific demand caused an increase in the price of crude oil immediately after the shock occurred and then an increase to a higher amount after 1 month. The results show that the price declined and again increased, but at the end of our horizon, it still remained higher than the primary price.

Coal prices gradually increased to a higher price in response to the oil-specific demand shock and remained at nearly the same price for 8 months, a statistically significant event. After that time period, the price of coal decreased to the initial price. Consequently, the precautionary demand of crude oil had a significant effect on oil and coal prices.

Uncertainty about the future price of oil has generated fear among crude oil consumers. Therefore, they have attempted to compensate for future shortfalls of oil with substitute fuels, namely coal. The price of oil increased immediately after an oil-specific demand shock occurred, while for coal the increase was gradual. This showed this specific demand slowly transferred to the coal market and its effect on coal was weaker than its effect on crude oil.

In addition, we showed in Zamani (2016), that a positive oil-specific demand shock had a positive and significant effect on the price of natural gas. We can interpret that oil-specific demand shock is, in fact, fossil-fuel-specific demand shock, which we will explore in the future.

Meanwhile, results show that oil-specific demand shock had no significant effect on oil production and it did have a significant effect on real activity. An unanticipated increase of the specific demand of oil led to an increase in real activity for approximately 3 months and after that, real activity fluctuated until returning to the initial amount after 10 months.

The important point here is the amount of the effect of demand shocks on coal prices. According to Figure 1, the effect of oil-specific demand shock on coal prices was smaller than the effect of global aggregate demand shock on coal prices. While oil-specific demand shock increased coal prices just for 5 months, aggregate demand shock increased the coal prices until 5 months, and then they fluctuated approximately around the same amount for 15 months. In other words, an unanticipated increase in global aggregate demand changed coal prices substantially for 15 months, and it is possible that the price increase will remain, while the effect of oil-specific demand was transitory and small just for about 5 months.

Additionally, Figure 1 demonstrates that coal price shock increased the real price of coal immediately for about 10 months, while it decreased real activity in a statistically significant fashion after about 3 months. As our data for world coal production was limited, we were not able to show that coal supply had suddenly decreased or coal demand had suddenly increased, which led to coal price shock. However, according to the results in Figure 1, as an increase in the real price of coal caused real activity to decrease substantially, we suppose coal price shock, here, happened because of a sudden decrease in the coal supply. Because coal is one important component of industrial commodities, its supply decline can have a significant effect on real activity, as our results show.

Thus, if we suppose during our period that coal supply shock can lead to coal price shock, coal price shock, with coal as a main substitute for oil, would cause an oil demand increase. Consequently, oil prices would increase to a higher amount. The results in Figure 1 support this assumption; a positive coal price shock had positive and statistically significant effects on oil prices.

Finally, Figure 1 illustrates that oil supply and demand shocks had a significant effect on coal prices, while just oil demand shocks had a significant effect on oil prices. Meanwhile, coal price shock had a significant effect on the real price of coal and crude oil.

3. CONCLUSION

The long-run relationship between crude oil and coal markets has been investigated. Researchers have found some evidence that there is a cointegration relationship between coal and oil markets in some regions of the world. In this research, we studied

the short-run relationship between coal and crude oil markets in the world by using the SVAR model and a new application of Kilian's (2009) index. Our results suggest that oil supply shock, aggregate demand shock, and oil-specific demand shock may affect coal prices. The effect of aggregate demand shock on coal prices is higher than that of other shocks. Furthermore, coal price shocks have a significant effect on the price of crude oil. As the crude oil market is more powerful than the coal market, the effect of the coal market on the oil market shows a high degree of substitutability between them.

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