

Chapter 1. Commodity Spot Market

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1. Introduction

Crude oil and natural gas have played a crucial role in our whole economy. In particular, the movement of oil price would give significant impacts to the economic condition. Despite that, the evaluation of macroeconomic performance in both empirical and theoretical analysis tends to rely on a common approach in which oil price or other commodity prices are assumed to be treated as exogenous variables. It implies that the interrelation between commodity prices and economy is ignored. However, as Barsky and Kilian (2004) emphasize, we believe that the oil prices should be endogenous in economic models.

This interim report aims to represent modeling approaches for commodity spot market (real market) including crude oil, natural gas, iron ore, and coking coal.

The rest of this paper is composed of four parts. Section 2 gives an overview of international commodity markets. Section 3 illustrates the basic framework in which crude oil spot price is determined, based on an assumption about the demand and supply in crude oil market. In addition, following this framework, we describe models for other commodity spot prices such as natural gas, iron ore and coking coal as well as crude oil. We also show empirical estimation results partially. Finally, Section 4 shows concluding remarks of this paper.

2. International Commodity Market

In this section, we provide an overview of international commodity market. The commodities trading are conducted in mainly two kinds of markets: the spot market and the derivatives market. Commodities can be divided into four different commodity categories: Energy (crude oil, heating oil, natural gas and gasoline), Metal (gold, silver, platinum and copper), Livestock and Meat (lean hogs, live cattle, feeder cattle, and pork), and Agricultural (wheat, corn, soybean, rice, cotton, and sugar). We show a list of representative international marketplaces where their commodities are traded.

(1) Chicago Board of Trade (CBOT)

The Chicago Board of Trade (CBOT) is the oldest commodity exchange. In particular, the CBOT is originally center in agricultural commodities trading such as wheat, corn and soybeans. There are the following delivery month contracts: March, May, July,

September, and December.

(2) Chicago Mercantile Exchange (CME)

The Chicago Mercantile Exchange (CME) is the world's leading derivatives marketplace for the trading of futures and options. In particular, the CME has large range of derivatives including interest rates, equity indices, foreign exchange, agricultural commodities, energy, weather, and real estate. The International Monetary Market (IMM), a division of the CME, is famous for the trading of currency and interest rate futures and options. Livestock commodities are mainly trading in the CME whereas agricultural ones are dealt with in the CBOT.

(3) Commodity Exchange (COMEX)

The Commodity Exchange (COMEX) is a marketplace where metals such as gold, silver, copper, and aluminum are traded.

(4) New York Mercantile Exchange (NYMEX)

The New York Mercantile Exchange (NYMEX) is one of the largest futures market exchange in the world. West Texas Intermediate (WTI) is benchmark of crude oil which is traded in the NYMEX.

(5) London Metal Exchange (LME)

The London Metal Exchange (LME) is the largest market of industrial metals trading in the world. It is the world center of non-ferrous metals trading. Trading activity known as Rings is conducted on trading floor, which facilitates the process of price discovery.

(6) London Finance Futures and Options Exchange (LONDON FOX)

The major commodities traded at the LONDON FOX are cocoa, coffee, and sugar.

(7) International Petroleum Exchange (IPE)

The International Petroleum Exchange (IPE) is one of the largest energy futures and options exchanges in the world. In particular, Brent Crude which is traded through the IPE is the global benchmark for oil prices.

(8) Dalian Commodity Exchange (DCE)

The Dalian Commodity Exchange (DCE) is Chinese commodity futures exchange

which is headquartered in Dalian, Liaoning province China. It was established in 1993 and one of the three major futures exchanges in China. The agricultural commodities used to be trade in the DEC. Today, the DCE has listed diverse commodities such as corn, corn starch, soybean, soybean meal, soybean oil, palm olein, fiberboard, blackboard, LLDPE, PVC, PP, coking coal, coke, iron ore etc.

(9) Shanghai Futures Exchange (SHFE)

In 1999, the Shanghai Futures Exchange (SHFE) was established after the merger of the Shanghai Metal Exchange, the Shanghai Commodity Exchange Shanghai, and the Shanghai Foodstuffs Commodity Exchange. Now, it is one of the largest commodity marketplaces in the world as well as in China.

(10)Tokyo Commodity Exchange (TOCOM)

The Tokyo Commodity Exchange (TOCOM) mainly deals with futures such as precious metals¹, petroleum oil, rubber, and agriculture (corn, general soybeans, and red beans). In 2017, TOCOM launched of the physical oil transaction.

(11)Osaka Dojima Commodity Exchange (ODE)

The Osaka Dojima Commodity Exchange (ODE) has listed Niigata Rice (Koshihikari), Tokyo Rice, Osaka rice, yellow corn and US soybeans, red beans, corn75 index, frozen shrimp, and raw sugar. In Japan, since wheat is sold at a particular price due to the grain price control by the Japanese government, wheat futures cannot be traded in Osaka and Tokyo, Japan.

(12)Tokyo Financial Exchange (TFX)

The Tokyo Financial Exchange (TFX) has listed products of interest rate futures contracts such as three-month Euroyen Futures, options of three-month Euroyen futures, six-month Euroyen LIBOR futures, over-night call rate futures, etc.

(13)Japan Electric Power Exchange (JEPX)

Since 2005, electric power transactions have been carried out at the Japan Electric Power Exchange (JEPX) in the process of electric power wholesale business liberalization led by the Ministry of Economy, Trade and Industry (METI) in Japan.

¹ As for gold, there are both cash and futures transactions.

(14) Chicago Climate Exchange (CCE) and European Climate Exchange (ECX)

Chicago Climate Exchange (CCE) and European Climate Exchange (ECX) are carbon market to trade emissions such as GFG emissions.

Thus, there are diverse markets in the world. In particular, we can see that the most of commodity market in the world is dominated by four marketplaces in the United States, namely CME, CBOT, COMEX and NYMEX.

3. Model for Commodity Spot Price

In this sections, we represent model specifications and their tentative estimation results about representative commodity spot markets (real markets) for crude oil, natural gas, other commodities (iron ore, and coking coal etc.).

3.1. Crude Oil Spot Price Determination

Kosaka (2015) and Shibata (2016) construct models in which prices of crude oil and natural gas are determined, based on the equilibrium between their demand and supply in crude real market. Their models begin with a definition of the aggregate crude oil demand function as follows:

$$X_{oil,t}^D = a_0 - a_1 p_{oil,t} + a_2 p_{oil,t-1} + a_3 \sum_{k=1}^N D_{oil,t}^k \quad (3.1)$$

where $X_{oil,t}^D$ denotes the aggregate crude oil demand at time t . $p_{oil,t}$ and $p_{oil,t-1}$ represent spot price of crude oil at times t and $t-1$, respectively. $D_{oil,t}^k$ means k -th country's crude oil demand. a_0 , a_1 , a_2 , a_3 are unknown parameters, where we assume $a_0 \geq 0$, $a_1 > 0$ and $a_3 > 0$. For crude oil market clearing, supply and demand balance holds $X_{oil,t}^D = X_{oil,t}^S$ ² = $X_{oil,t}$, where $X_{oil,t}^S$ represents the aggregate crude oil supply at time t . Following this balance and rearranging equation (3.1), crude oil spot price is derive as:

$$p_{oil,t} = b_0 + b_1 p_{oil,t-1} + b_2 \sum_{k=1}^N D_{oil,t}^k - b_3 X_{oil,t}^S \quad (3.2)$$

where b_0 , b_1 , b_2 , and b_3 are unknown parameters. Equation (3.2) implies that the crude oil spot price at time t depends on that at time $t-1$, the summed demand for crude oil, and the world crude oil production.

Furthermore, in order to take into consideration the affect of price volatility by speculation. We redefine equation (3.2) by adding the error term $u_{oil,t}$ as:

² Although supply of crude oil and natural gas is endogenized in Kosaka (2015) and Shibata (2016), this interim report focuses only on the determination of commodity prices. We intend to deal with the supply side of commodity market in future work.

$$p_{oil,t} = b_0 + b_1 p_{oil,t-1} + b_2 \sum_{k=1}^N D_{oil,t}^k - b_3 X_{oil,t}^S p_{oil,t} + u_{oil,t}^3 \quad (3.3)$$

Here, we modify equation (3.3) in order to enhance the applicability for empirical analysis. We use Indices of Industrial Production (IIP) as the alternative variable of the aggregate demand for crude oil ($\sum_{k=1}^N D_{oil,t}^k$) because it is actually difficult to gain the data of crude oil demand of each country. Thus, we can rewrite the determination of spot price as follows:

$$p_{oil,t} = b_0 + b_1 p_{oil,t-1} + b_2 \sum_{k=1}^N (x_{IIP,t}^k / e^k) - b_3 X_{oil,t}^S p_{oil,t} + u_{oil,t} \quad (3.4)$$

where $x_{IIP,t}^k$ is the Index of Industrial Production (IIP) of k -th country and e^k is the exchange rate of k -th country. b_0 , b_1 , b_2 and b_3 are unknown parameters, which are identified by econometrics. The third term reflects the level of the aggregate oil demand in the world. In particular, k -th country's IIP divided by k -th exchange rate implies to evaluate purchasing power parity (PPP). If the currency of k -th country's depreciates, it shows that PPP falls

Table 3.1 reports the tentative empirical result of crude oil spot price (WTI) by using IIP and aggregate crude oil supply of Canada. Statistics shows that price can be estimated.

Table3.1. The Estimation Result of Crude Oil Spot Price (WTI)

Explanatory Variables	Coefficient	S.E.
Supply of Crude Oil of the United States	-0.009***	0.001
IIP of Canada / Exchange Rate of Canada	-0.608***	0.153
Constant	98.444***	22.084
Observation		77
Adj. R-squared		0.621

Note: Adj. R-Squared is adjusted R-squared. *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$, respectively.

3.2. Natural Gas Spot Price Determination

The importance of natural gas as an energy source has increasingly grown. Hence, we also consider the natural gas spot price as well as crude oil spot price. Following (3.4), the natural gas spot price $p_{gas,t}$ is defined as

³ Kosaka (2015) and Shibata (2016) take into account the substitution of spot price between crude oil and natural gas.

$$p_{gas,t} = c_0 + c_1 \sum_{k=1}^N (x_{IIP,t}^k / e^k) - c_2 X_{gas,t}^S p_{oil,t} + u_{gas,t} \quad (3.5)$$

where $X_{gas,t}^S$ shows the aggregate supply of natural gas at time t . c_0 , c_1 , and c_2 are unknown parameters.

Table 3.2 represents the empirical result of natural gas spot price (Henry Hub) by using IIP and aggregate crude oil supply of the United States. The results would not be satisfactory.

Table3.2. The Estimation Result of Natural Gas Spot Price (Henry Hub)

Explanatory Variables	Coefficient	S.E.
Supply of Crude Oil of the United States	-0.000***	0.000
IIP of the United States	0.237***	0.045
Constant	-4.348	3.063
Observation		78
Adj. R-squared		0.436

Note: Adj. R-Squared is adjusted R-squared. *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$, respectively.

3.3. Other Commodities Spot Price Determination

Prices of industrial metals such as iron ore, copper, aluminum, zinc, and coking coal tend to attract less attention than one of crude oil or natural gas. However, they would be definitely essential commodities in modern industrialized economy.

3.3.1. Iron Ore Spot Price Determination

The iron ore is central to the world economy because it is the main raw material for steel which is required to produce building, ships, and cars. The iron ore market had been unclear until 2010 because price determination was based on annual contracts via private negotiations between suppliers and the big steel producers. This traditional transaction system has been changed due to an increase of the demand by China. Now, the pricing power of iron ore by China has been increasing. We apply equation (3.4) for explaining iron ore price determination. Hence, the iron ore spot price $p_{iore,t}$ is set as:

$$p_{iore,t} = d_0 + d_1 \sum_{k=1}^N (x_{IIP,t}^k / e^k) - d_2 X_{iore,t}^S p_{oil,t} + u_{iore,t} \quad (3.6)$$

where d_0 , d_1 , and d_2 are unknown parameters. Additionally, we estimate this model

(3.6) by using the data China Iron Ore Import Price (CFR Tianjin port) as the iron ore spot price. The estimation result is shown in Table 3.3.

Table3.3. The Estimation Result of Iron Ore Spot Price (China Iron Ore)

Explanatory Variables	Coefficient	S.E.
Supply of Iron Ore	209.653	20.062
IIP of China / Exchange Rate of China	0.549	0.215
Seasonal Dummy January	27.070	10.244
Seasonal Dummy April	28.436	10.648
Seasonal Dummy May	25.22	10.677
Seasonal Dummy August	16.766	10.571
Constant	-150.015	28.954
Observation		110
Adj. R-squared		0.497

Note: Adj. R-Squared is adjusted R-squared. *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$, respectively.

3.3.2. Coking Coal Spot Price Determination

Lastly, we consider the coking coal spot price $p_{cok,t}$. The same as the above, the following equation is defined as:

$$p_{cok,t} = g_0 + g_1 p_{cok,t-1} + g_2 \sum_{k=1}^N (x_{IIP,t}^k / e^k) - g_3 X_{cok,t}^S p_{oil,t} + u_{cok,t} \quad (3.7)$$

where g_0 , g_1 , and g_2 are unknown parameters. The estimation results of this model is reported in Table 3.4.

Table3.4. The Estimation Results of Coking Coal Spot Price

Explanatory Variables	Coefficient	S.E.
Supply of Crude Oil in the United States	-0.009***	0.001
IIP of Canada / Exchange Rate of Canada	-0.608***	0.153
Constant	98.444***	22.084
Observation		77
Adj. R-squared		0.621

Note: Adj. R-Squared is adjusted R-squared. *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$, respectively.

In this paper, we address representative commodities (crude oil, natural gas, iron ore, and coking coal). However, there is other commodities, which would give significant impacts on economic growth: other basic metals (aluminum and nickel), livestock (beef,

pork, and broiler), and agriculture (corn, soybeans, wheat, and cotton). We believe that we should explain the whole macroeconomic model by endogenizing their prices.

4. Conclusion

In this paper, we give overview of commodities market and represent model specifications of spot prices focusing on representative commodities such as crude oil, natural gas, iron ore, and coking coal. Our model can explain the movement of spot price in the context of supply/demand.

In future work, we intend to cover other commodities real prices: other basic metals (aluminum and nickel), livestock (beef, pork, and broiler) and agriculture (corn, soybeans, wheat, etc.). Furthermore, we attempt to link this model for spot price with commodity futures markets and a macroeconomic model. We believe that developing the link model enables to be application to policy analysis on global economic issues.

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