Journal of Korea Trade Vol. 23, No. 2, April 2019, 34-45
https://doi.org/10.35611/jkt.2019.23.2.34
ISSN 1229-828X

Lead-Lag Relationships between Import Commodity Prices and Freight Rates: The Case of Raw Material Imports of Korea

JKT 23(2)

Received 1 June 2018
Revised 31 October 2018
Accepted 5 December 2018

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Abstract

Purpose – This study investigates the lead-lag relations between the prices of major commodities imported into Korea and corresponding shipping freight rates. This paper aims to provide implications for cross-market causal relations between related economic segments.
Design/Methodology - For economic long-run equilibrium between commodity prices and freights, a Johansen (1988) cointegration test is employed first. Then, Granger (1987) causality tests are performed under the vector error correction model (VECM) framework.
Findings - The results indicate that the direction of causality varies by raw materials, which is attributable to different economic mechanisms in the corresponding shipping transportation sectors. In addition, the significance of causality becomes blurred during the post-2008 period.
Practical Implication - Corporate managers in commodity trading, steelmaking, power generation, and oil refinery sectors can take advantage of the findings in this study as identifying leading economic indicators can be helpful for decision making in both short- and long-term strategies.
Originality/value - This study is the first attempt to analyze the inter-relations between commodity prices and corresponding freight rates focusing on raw material imports of Korea.

Keywords: Commodity Price, Freight Rate, Lead-Lag Relationship, Raw Material Import
JEL Classifications: F14, F17, L92

1. Introduction

This study investigates lead-lag relationships between major import commodities of Korea and corresponding freight rates. According to the statistics released by the Korea International Trade Association (KITA), Korea ranked the 6th largest export powerhouse in 2017, reaching $573.9 billion, ahead of any other year during in the past seven decades. However, as the country lacks in natural resources, the export-driven economy has had to depend on imports from foreign countries for raw material consumptions.[1] Despite the economic significance of commodity imports (Kim Kee-Hwa, 2005) and their far-reaching impacts on domestic producer and consumer prices (Lee Ik-No, 2006), employment (Nahm Pyeong-Tak, 2013), regional economies, the balance of payment (Son Yong-Jung, 2008), and ultimately, national welfare (Hwang Yun-Seop and Kim Na-Yeah, 2012), little academic attention has been paid to the research topic of the import price of raw materials.

In this paper, we focus on the probable economic linkage between prices of raw materials imported to Korea and corresponding shipping freight rates. The topic of the lead-lag relationship between two related economic time series has received a great deal of attention from both academia and practitioners alike. Exploiting information from the lead-lad

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relations can be useful for decision making for both short- and long-run corporate strategies. For instance, when there exists a uni-directional lead-lag relation between two economic variables, one variable reacts to any economic shocks in the market faster than the other. Then, the faster reacting variable can be used as a leading indicator for the slower one. Therefore, corporate managers are able to establish strategies more effectively by incorporating information from the leading indicator.

The extant literature devoted to the price of imported goods into Korea largely examines its economic relation with foreign exchange rates (Cha Hye-Kyung, 2008; Zhu Shi-You, Lee Min-Hwan and Hwang Kyu-Sun, 2010) and the stock market index (Kang In-Cheol, 2012; Lim Dae-Bong, 2009; Park Seong-Bin and Park Moo-Hyun, 2014). This paper fills the gaps in current research by presenting empirical evidence on the lead-lag relations between commodity prices and corresponding freight rates. Given the fact that shipping transportation facilitates approximately 90% of the world trade of merchandise goods in terms of volume, it is of particular importance to investigate the economic relation between commodity prices imported into Korea and freight rates for servicing the seaborne trade routes.[2] In addition, as the share of transportation costs is relatively large for raw materials when compared to other types of merchandise goods, it is likely that commodity prices might be significantly sensitive to the freight rates, or vice versa. In fact, financial investors pay particular attention to the use of shipping indexes as leading indicators of economic activity.[3] For instance, considering that the Baltic Dry Index (BDI) is a comprehensive index of shipping freight rate for the carriage of dry bulk commodities (such as iron ore and coal), it is likely that the shipping index can be used as a gauge of the economic situation since it reflects demand for raw materials for manufacturing production. In this light, a strand of literature is devoted to examine the possibility that economists can take advantage of a shipping index as a leading indicator for stock returns (Bakshi, Panayotov and Skoulakis, 2011) or national GDP growth (Bildirici, Kayikci and Onat, 2015/2016). To the best of our knowledge, this is the first attempt to examine the lead-lag relations between the price of major commodities imported into Korea and corresponding freight rates.

This paper pays particular attention to import of raw materials.[4] To this end, we first examine the statistics for imports into Korea during the period of 2000-2017 provided by K-Statistics, a trade information service offered by KITA.[5] Among the major import items by four-digit MTI code, we choose the top three commodities in terms of volume (metric ton). These are crude oil (MTI 1310), bituminous coal (MTI 1322), and iron ore (MTI 1120). The combined share of the three commodities among the total imports of Korea in 2017 was 58.7% and 16.4% in terms of weight (metric ton) and monetary amount (US dollar), respectively. Figure 1 offers an overview of imports of the raw materials imported into Korea during the 2000-2017 period.

Our investigation yields several interesting findings. First, the results of a Johansen (1988) cointegration test suggest that there exists long-run equilibrium between the import prices of major commodities (iron ore, bituminous coal, and crude oil, respectively) and the

[1] For example, the energy imports of Korea reached $81 billion, as much as 94.7% of its energy consumption, in 2016 (Korea Energy Economics Institute).

[2] The number on the shipping transportation's share of world trade is retrieved from the International Chamber of Shipping (http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade).

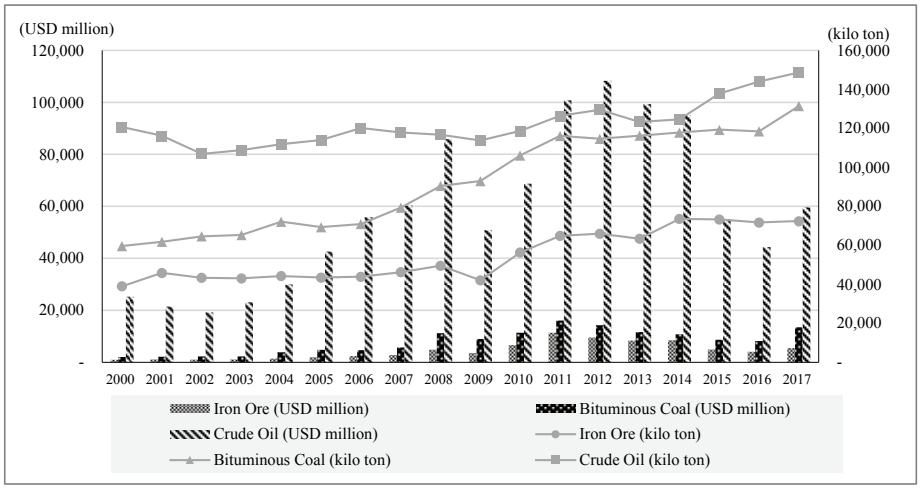
[3] See 'How Big a Worry is the Baltic Dry Index?', *The Wall Street Journal* (9th July 2010).

[4] The terms 'commodity' and 'raw material' are used interchangeably in this paper. In economics, the term commodity generally refers to goods and services that have full or substantial fungibility, Therefore, a good is regarded as equivalent regardless of the entities who produced it: for example, raw materials, agricultural products, and natural resources.

[5] https://stat.kita.net/main.screen

corresponding freight rates (Capesize C5, Panamax P3A and VLCC TD3, respectively).[6] Second, despite the long-run association, the direction of causality varies among the individual pairs of commodity prices and freight rates, which can be attributable to the different supply-demand relations in the sub-sectors of the shipping transportation industry. Finally, we find that the distinction of causal relations has been blurred since the second half of 2008, when the global shipping market collapsed.

Fig. 1. Imports of Major Commodities into Korea 2000-2017



Source: Korea International Trade Association (2018).

The rest of this study is structured as follows: Section 2 reviews previous literature on the economic relationships between commodities and transportation. Section 3 presents the economic framework and methodologies employed in this study. Section 4 describes the dataset of major commodity prices and freight rates. Section 5 presents the results of cointegration and causality tests, respectively. Finally, Section 6 concludes the paper.

2. Literature Review

The topic of the lead-lag relationship, or cross-market information linkage, has attracted a great deal of attention from both academia and practitioners alike. In perfectly efficient markets, new economic shocks are incorporated into prices simultaneously. Therefore, there is no time delay, and prices adjust to new long-run equilibriums. However, due to market friction such as information asymmetry and transaction costs, the speed of adjustment is different in various markets. As a consequence, some prices react faster to economic shocks and play a leading role. Broadly, the lead-lag relationship between two markets has been examined in three categories: (1) the association between supply and demand factors (e.g. Kavussanos, Visvikis and Dimitrakopoulos, 2014), (2) the association between spot and

[6] In each sub-sector of shipping transportation, vessels are classified into different categories per cargo-carrying capacity. The Capesize refers to vessels with a cargo-carrying capacity of more than 80,000 deadweight ton (dwt). The Panamax refers to vessels with a cargo-carrying capacity between 60,000-75,000 dwt. The VLCC (Very Large Crude oil Carrier) refers to vessels with a cargo-carrying capacity of more than 160,000 dwt.

derivatives markets (e.g. Coppola, 2008), and (3) the association between different derivatives markets (e.g. Chulia and Torro, 2008). The subject of this paper falls into the first category dealing with supply (freight rates) and demand (commodity prices) of the shipping transportation market.

There have been a limited number of studies that examine the economic relations of prices of raw materials imported into Korea with related economic variables. The vast majority of literature in this research area focuses on the impact of fluctuations in Korean Won/US Dollar exchange rates and the information spillover effect with stock market volatility. Regarding the impact of foreign exchange rates, Cha Hye-Kyung (2008) found that the exchange rate pass-through to import prices in Korea increased over time. Zhu Shi-You, Lee Min-Hwan, Hwang Kyu-Sun (2010) examined the impact of exchange rate pass-through to import prices and consumer prices in Korea using a structural vector autoregressive model. Cha Hye-Kyung (2012) documented that, on average, a 10% increase in the Korean Won/US Dollar exchange rate exerted a 5.5% increase in the import prices of raw materials. The author also found that the impact of the exchange rate pass-through was asymmetric, which indicates that the changes in the import price are more significant when the exchange rate increases.

Lim Dae-Bong (2009) explored the lead-lag relation between the Dubai crude oil price and the Korea Composite Stock Price Index (KOSPI) for the 1993-2008 period. The author documented a uni-directional causal relation running from the KOSPI to the crude oil price. In sharp contrast, Yoo Han-Soo (2014) found that the raw material market informationally leads the Korean stock market by presenting the results of causality running from the Rogers International Commodity Index (RICI) to the KOSPI.[7] Kang In-Cheol (2012) examined the information spillover effect between the crude oil price and the stock prices of Korean firms. The author documents that the stock price volatility of mid-sized firms was more sensitive to changes in oil price than those of large-sized and small-sized firms. Park Seong-Bin and Park Moo-Hyun (2014) found that the global stock market was positively associated with oil price, while sudden shocks from the oil supply side caused short-run deviation from the long-run equilibrium.

Regarding cross-market linkages between commodities and transportation, Kavussanos, Visvikis and Dimitrakopoulos (2010) explored the existence of the spillover effect between shipping derivatives (Forward Freight Agreements, FFAs) and futures contacts written on commodities transported by Panamax vessels.[8] They documented that the two markets were inter-connected, while the spillover effect runs stronger from commodity futures to shipping derivatives, which indicates that the commodity market informationally leads the shipping freight market. In another study, Kavussanos, Visvikis and Dimitrakopoulos (2014) also documented similar results of the stronger leading role of commodity prices compared to freight rates in the dry-bulk shipping sector. Tsioumas and Papadimitriou (2016) investigated lead-lag relationships between commodities (coal, iron ore, and wheat) and corresponding freight rates. They found the existence of causality running from commodity prices to freight rates for the carriage of coal and iron ore, while the direction of causality was diametrically opposite for the carriage of wheat.

From the review of the previous literature above, it is obvious that the investigation of economic linkages between raw materials and corresponding freight rates can provide

[7] The RICI is a composite index of commodity futures designed by Jim Rogers in 1996. The index tracks the value of 38 commodity futures (ranging from agricultural to energy and metal products) from 13 global exchanges. For the details of the index, see its website (http://www.rogersrawmaterials.com/home.asp).

[8] FFAs are financial derivatives contracts between a seller and a buyer who agree to settle a freight rate, for a pre-specified quantity of cargo or type of ship. For the details of the shipping financial derivatives, see Kavussanos and Visvikis (2006/2011).

valuable insight into the international trade of Korea. However, to our best knowledge, there is no study exploring major commodities imported into Korea and freight rates servicing these transactions. Therefore, this study can offer important implications for the international trade of Korea and shipping logistics alike by filling gaps in the current research.

3. Methodology

According to Engle and Granger's (1987) definition, when a pair of time-series are non-stationary individually, but their linear combination becomes stationary, the two series are cointegrated. In the economic spectrum, the cointegration indicates that the variables exhibit a long-run equilibrium adjusting to the equilibrium direction despite the short-run deviations. Accordingly, we perform a cointegration test to examine whether there exists a long-run equilibrium association between commodity prices and corresponding freight rates. The possible cointegrated relations are investigated through Johansen (1988) tests with null hypotheses of no cointegration and at most one cointegration. Johansen (1988) suggests two likelihood ratio statistics for the test of the number of cointegration vectors using the trace and the eigenvalue. If the two values are greater than the critical values, a pair of time-series are said to be cointegrated. The calculations of the likelihood ratio statistics are as follows:

$$\lambda_{trace} = -2\ln(Q) = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i) \tag{1}$$

$$\lambda_{max} = -2\ln(Q) = -T\ln(1-\hat{\lambda}_{r+1}) \tag{2}$$

If a pair of time-series are cointegrated, the Granger (1969) causality is tested under the Vector Error Correction Model (VECM) framework. The bi-variate VCEM of the commodity prices and corresponding freight rates are estimated with the following equations:

$$\Delta Commodity_t = c_1 + \sum_{i=1}^{p}\alpha_{1i}\Delta Commodity_{t-i} + \sum_{j=1}^{p}\beta_{1j}\Delta Freight_{t-j} + \gamma_1 ECT_{t-1} + \varepsilon_{1t} \tag{3}$$

$$\Delta Freight_t = c_1 + \sum_{i=1}^{p}\alpha_{2i}\Delta Commodity_{t-i} + \sum_{j=1}^{p}\beta_{2j}\Delta Freight_{t-j} + \gamma_2 ECT_{t-1} + \varepsilon_{2t} \tag{4}$$

where α, β, and γ are coefficients, and p is the optimal number of lags. $ECT_{t-1}$is the error correction term containing information on the long-run relationship between the pair of variables. The null hypothesis of the Granger test is that all coefficients are zero. The rejection of the null hypothesis indicates either a uni-directional or a bi-directional causality between the two time-series. For example, from the above equations, (1) the rejection of the null hypothesis (H_0: $\alpha_{1i} = \beta_{1j} = 0$) indicates a uni-directional causality running from freight rates to commodity prices; (2) the rejection of the null hypothesis (H_0: $\alpha_{2i} = \beta_{2j} = 0$) indicates a uni-directional causality running from commodity prices to freight rates; (3) the rejection of the both null hypotheses (H_0: $\alpha_{1i} = \beta_{1j} = 0$ and H_0: $\alpha_{2i} = \beta_{2j} = 0$) indicates a bi-directional causality between commodity prices and freight rates. The use of the Granger causality test and VECM is fairly popular among researchers documenting the lead-lag relationships between commodity prices and shipping freight rates (see Chen Shun, Meersman and van de Voorde, 2010; Hsiao Yao-Jen, Chou Heng-Chih and Wu Chun-Chou, 2014; Kavussanos, Visvikis and Dimitrakopoulos, 2014; Li *et al*., 2014, to name a few).

4. Data Description

The dataset for the calculation of commodity import prices in Korea comes from the K-Statistics of KITA. Since, to our best knowledge, there is no reliable and comprehensive index of import prices of raw materials, the import amounts of major commodities in terms of US dollar and metric ton are retrieved from the trade statistics database on a monthly basis.[9] Then, the monthly import price of each commodity is calculated by dividing the import amount of the monetary term (US dollar) by the import amount of the volume term (metric ton). This process allows us to obtain the monthly price per ton of imported goods covering the January 2000 to March 2018 period (219 observations). In this study, we choose the top three import items in terms of weight (metric ton). The major import commodities include iron ore, bituminous coal, and crude oil in terms of the four-digit MTI codes of 1120, 1322, and 1310, respectively.

Table 1. Summary Statistics of Monthly Commodity Import Prices and Freight Rates, January 2000 to March 2018

		Obs.	Mean	Std. Dev.	Skewness	Kurtosis	J-B	ADF	KPSS
IRON	$/ton	219	75.141	46.226	0.701	2.442	20.797***	-1.579	0.989***
COAL	$/ton	219	79.502	33.697	0.264	2.168	8.855**	-1.637	1.069***
OIL	$/ton	219	471.460	231.994	0.415	1.894	17.451***	-2.111	0.886***
C5	$/ton	219	23.993	17.388	2.132	8.210	413.674***	-3.389**	0.308
P3A	$/day	185	19,576.300	17,136.000	1.707	5.966	157.681***	-2.948**	0.815***
TD3	$/ton	216	76.886	44.177	1.981	8.021	368.075***	-5.296***	0.754***

Notes: 1. This table reports summary statistics of monthly prices during the January 2000 to March 2018 period.
2. The freight rates for the Panamax P3A route were reported from January 2003, and those for the VLCC TD3 route were reported between January 2000 and December 2017.
3. IRON is the iron ore (MTI 1120) price (US dollar per metric ton) imported to Korea. COAL is the bituminous coal (MTI 1322) price (US dollar per metric ton) imported to Korea. OIL is the crude oil (MTI 1310) price (US dollar per metric ton) imported to Korea. C5 is the freight rate (US dollar per metric ton) of voyage charters for the Capesize C5 route (Wes Australia/Beihub-Baoshan). P3A is the freight rate (US dollar per day) of time-charters for the Panamax P3A route (Japan-South Korea/Pacific). TD3 is the freight rate (US dollar per metric ton) of voyage charters for the VLCC TD3 route (Middle East Gulf/Japan).
4. Obs. is the number of observations. Mean is the sample mean of the time-series. Std. Dev. is the estimated standard deviation. Skewness and Kurtosis are the estimated third and fourth moments, respectively, of the data. J-B is the Jarque and Bera (1980) test for normality. ADF is the Augmented Dickey-Fuller (1981) test for unit root, and KPSS is the stationary test of Kwiatkowski *et al.* (1992).

The dataset of the freight rates is retrieved from the Baltic Exchange. The Baltic Exchange provides several composite indices representing the level of freight rates for certain vessel types, such as the Baltic Dry Index (BDI) for the dry-bulk sector, and the Baltic Dirty Tanker Index (BDTI) for the crude oil tanker sector.[10] However, as this study focuses on commodity

[9] The Bank of Korea provides the time-series of price index for imported goods via the Economic Statistics System. However, the dataset for raw materials begins from January of 2005. Therefore, the dataset from K-Statistics is selected for this study as it covers a longer time span.

[10] While the BDI is a composite index for the cost of sea transportation for the carriage of dry-bulk cargos such as iron ore, coal, and grains, the BDTI is a corresponding composite for the carriage of a variety of unrefined oils.

imports into Korea, it is more reasonable to select freight rates for individual routes relating to Korean sea transportation. Therefore, we choose specific routes corresponding to commodity imports of Korea that constitute representative indicators as following: the Capesize C5 route (West Australia/Beihub-Baoshan) for iron ore; the Panamax P3A route (Japan-South Korea/Pacific) for bituminous coal; and the VLCC TD3 route (Middle East Gulf/Japan) for crude oil.[11]

Table 1 provides the summary statistics of commodity import prices and the corresponding freight rates of component routes. Mean is the sample mean of the time-series and Std. Dev. is the estimated standard deviation. All series exhibit positive skewness. Time-series of freight rates (C5, P3A and TD3) have significantly excess kurtosis, while those of commodity prices (IRON, COAL, OIL) are platykurtic. J-B is the Jarque-Bera (1980) test for normality. The results indicate departures from normality for all time-series of prices in the sample. ADF is the Augmented Dickey-Fuller (1981, ADF) test for unit root with the null hypothesis that the time-series has a unit root. The results of the ADF test indicate that each time-series of commodity price has a unit root, while that of freight rate does not. However, except for C5, the results of KPSS (Kwiatkowski et al., 1992) fail to provide support for the stationary assumption. Therefore, it can be concluded that the time-series of commodity prices and freights are non-stationary, except for C5.

5. Empirical Results

Having examined the stationarity of commodity prices and the corresponding freight rates, we investigate the cointegration relationship between the pairs of time-series data as a next step. Table 2 presents the results of the Johansen (1988) cointegration tests with the null hypotheses of no cointegration (r=0) and, at most, one cointegration (r≤1) between two variables. The λ_{trace} and λ_{max} statistics indicate the existence of the long-run relation between the two time-series of commodity prices and freight rates. As shown in Table 2, the results indicate that the price of raw materials and the corresponding freight rates are cointegrated during the sample period. The test statistics are significant, rejecting the null hypotheses at the 1% or 5% levels.

Table 2. Cointegration Test Results from Commodity Prices and Freight Rates

	Lags	H_0	λtrace	95% Critical Value	Prob.	λmax	95% Critical Value	Prob.
Iron Ore	q=1	r=0	16.849	15.495	0.031**	14.459	14.265	0.047 **
and C5		r≤1	2.390	3.841	0.122	2.390	3.841	0.122
Bituminous	q=1	r=0	29.618	15.495	0.000***	22.798	14.265	0.002 ***
Coal and P3A		r≤1	6.820	3.841	0.009***	6.820	3.841	0.009 ***
Crude Oil	q=1	r=0	37.082	15.495	0.000***	31.396	14.265	0.000 ***
and TD3		r≤1	5.685	3.841	0.017**	5.685	3.841	0.017 **

Notes: 1. This table reports the Johansen test results of co-integration between commodity prices and corresponding freight rates.
2. The null hypotheses (H_0) are of no co-integration (r=0) and, at most, one co-integration (r≤1).
3. *p<0.1, ** p <0.05, *** p <0.01.

[11] For the details of the route specifications, see the website of the Baltic Exchange (www.balticexchange.com).

As the results of Johansen tests suggest the existence of a long-run cointegrated relation between commodity prices and freight rates, we then carry out Granger (1969) causality tests based on the VECM framework to examine the lead-lag relation between the two variables. Before performing the causality tests, it is important to determine the optimal numbers of time-lag. We use both Akaike Information Criteria (AIC, 1973) and Schwarz Bayesian Information Criteria (SBIC, 1978). The AIC indicates the optimal number of lags are 4, 1, and 3 for the pairs of Iron Ore-C5, Bituminous Coal-P3A, and Crude Oil-TD3, respectively. In contrast, the SBIC indicates the optimal number of lags are 1, 1, and 2 for the pairs of Iron Ore-C5, Bituminous Coal-P3A, and Crude Oil-TD3, respectively. When the optimal lag numbers are different between the information criteria, we select the shorter term in order to make the models parsimonious.

Table 3 reports the causal relationship between commodity prices and freight rates estimated under the VECM framework. Panel A presents the results of Granger causality tests for the whole sample period (2000-2018). As shown, the results suggest that the direction of causality differs by commodities and freight rates of the vessel that perform the carriage of the corresponding cargos. For the association between the iron ore price and the Capesize C5 route, we find a uni-directional causality running from the freight rates to the commodity prices. In sharp contrast, there exists uni-directional causality running from the commodity prices to the freight rates in the relationship between crude oil prices and the VLCC TD3 route, which is diametrically opposed to the iron ore-C5 pair. For the relationship between bituminous coal and the Panamax P3A route, we find a bi-directional causality between the two variables.

The divergence of the directions of causal relation between commodity prices and freight rates can be possibly explained by the different economic mechanisms affecting the individual sub-sectors of shipping transportation markets. Kavussanos (1997) documented that freight rates for larger vessels (Capesize) were considerably more volatile than those for smaller vessels (Panamax) in the dry-bulk segment since large-sized vessels have less opportunities for employment due to limitations such as the choice of cargo shipped and the water depth of calling ports.[12] For example, a Capesize vessel can carry either iron ore or coal, while a Panamax vessel can have a wider range of cargo selection including coal, grains, iron ore, bauxite, and sulphur. Therefore, it is reasonable to expect that the Capesize shipping freight market is more informationally efficient than the Panamax market since the sector services the carriage of specific kinds of cargos, which indicates that there is less intervention in information transmission between freight and commodity markets.

Another possible explanation for the bi-directional causality between coal prices and Panamax freight rates can found in the nature of the shipping freight contract. While the Capesize freight rate (C5) used in this research is for a spot contract, the Panamax freight rate (P3A) is for a time-charter contract.[13] As the freight rate for a time-charter contract is long-term (usually at least six months), its speed of adjustment is slower than that for a spot contract. In addition, the finding of the uni-directional causality from freight rates to commodity prices in this study supports the possibility that an index of shipping freight rates can be used as a leading indicator for economic activity in the commodity markets, consistent with the findings in some previous studies reporting that BDI informationally leads global stock markets (Bakshi, Panaytov, Skoulakis, 2012) and GDP growth of the USA (Bildirici, Kayikci and Onat, 2015/2016).

[12] Since a Capesize vessel is larger than a Panamax vessel, it needs a much longer draft, which is the vertical distance between the waterline and the bottom of the hull. Therefore, a Capesize vessel has a limited number of calling ports due to the limit of water depth in a great number of ports around the world.

[13] Unfortunately, there is no reliable source of spot freight rates for Panamax routes specific to Korea.

Table 3. Granger Causality of Commodity Prices and Freight Rates

	Iron Ore-C5		Bituminous Coal-P3A		Crude Oil-TD3	
	$\Delta Commodity_t$	**$\Delta Freight_t$**	**$\Delta Commodity_t$**	**$\Delta Freight_t$**	**$\Delta Commodity_t$**	**$\Delta Freight_t$**
Panel A: 2000-2018						
ECT_{t-1}	-0.003***	0.003***	0.005***	-2.771***	-0.005**	-0.017***
$\Delta Commodity_{t-1}$	0.207***	-0.093*	-0.160**	-46.241	0.886***	0.142**
$\Delta Commodity_{t-2}$					-0.275***	-0.008
$\Delta Freight_{t-1}$	0.117**	0.367***	0.000*	0.281***	0.089*	-0.025
$\Delta Freight_{t-2}$					0.072	-0.051
c	0.200	0.031	0.526	18.178	0.547	-0.257
Granger Causality (H_0)	F-statistics	*p*-value	F-statistics	*p*-value	F-statistics	*p*-value
Commodity ≠> Freight	1.373	0.243	8.733	0.004	3.498	0.032
Freight ≠> Commodity	13.079	0.000	9.744	0.002	1.480	0.230
Panel B: 2000-2008						
ECT_{t-1}	-0.059***	0.018	0.051***	-50.671***	0.002	0.013***
$\Delta Commodity_{t-1}$	-0.152*	-0.429***	-0.561***	66.495	1.070***	0.329**
$\Delta Commodity_{t-2}$					-0.329***	-0.157
$\Delta Freight_{t-1}$	0.015	0.498***	0.000	0.296***	0.062	0.049
$\Delta Freight_{t-2}$					0.076*	-0.002
c	0.917	0.335	2.618***	-239.731	-0.135	-0.275
Granger Causality (H_0)	F-statistics	*p*-value	F-statistics	*p*-value	F-statistics	*p*-value
Commodity ≠> Freight	12.079	0.001	5.721	0.020	2.405	0.095
Freight ≠> Commodity	25.109	0.000	3.137	0.081	0.095	0.909
Panel C: 2009-2018						
ECT_{t-1}	-0.005	0.016***	-0.063***	11.788*	-0.005	-0.010***
$\Delta Commodity_{t-1}$	0.363***	0.020	0.010	-96.608**	0.752***	0.026
$\Delta Commodity_{t-2}$					-0.251***	0.016
$\Delta Freight_{t-1}$	0.101	0.101	0.000	0.045	0.105	0.035
$\Delta Freight_{t-2}$					-0.179	0.063
c	-0.147	0.063	-0.301	45.027	0.759	-0.164
Granger Causality (H_0)	F-statistics	*p*-value	F-statistics	*p*-value	F-statistics	*p*-value
Commodity ≠> Freight	1.766	0.187	0.008	0.927	1.118	0.331
Freight ≠> Commodity	0.651	0.422	6.089	0.015	0.907	0.407

Notes: 1. This table reports the results of the Granger causality test for the lead-lag relationship between commodity prices and corresponding freight rates.
2. While $\Delta Commodity_t$ represents the log first difference of individual commodity prices (i.e. iron ore, bituminous coal and crude oil) at the time of *t*, $\Delta Freight_t$ represents the log first difference of individual freight rates (i.e. Capesize C5, Panamax P3A and VLCC TD3).
3. '≠>' denotes the null hypothesis of Granger causality test "does not Granger cause".
4. **p*<0.1, ** *p* <0.05, *** *p* <0.01.

On the other hand, the shipping transportation market for the carriage of crude oil is rather different from the dry-bulk market. Generally, the speed of adjustment to a new economic shock in the tanker shipping sector is known to be slower than that of the dry-bulk sector (Kou Ying, Liu Li-Ming and Luo Mei-Feng, 2014). Since a number of shippers (major oil companies) own tanker fleets for their own transportation purposes (Haralambides, Tsolakis and Cridland, 2004), a large part of the crude oil transportation market is controlled by cargo owners. Moreover, oil companies have a much greater deal of economic interest in commodity prices than in freight rates as the share of profit from oil trading is larger than that from efficient oil transportation planning. Therefore, it can be conjectured that the

commodity market is more informationally efficient than the transportation market in the crude oil sector as there exists a great deal of market intervention by cargo owners. Alternatively, since, in sharp contrast to the dry-bulk sector, the tanker sector is controlled by relatively smaller number of rich shipowners (e.g. major oil companies), the level of competition is much less severe. Therefore, the tanker sector reacts to economic shocks less actively. Kou Ying, Liu Li-Ming and Luo Mei-Feng (2014) documented similar empirical evidence on the direction of causality between newbuilding and second-hand prices in the dry-bulk and tanker sectors, respectively.

Furthermore, we examine whether there exists any structural break in the causal relationship between commodity prices and freight rates around the financial meltdown in 2008. Table 3 reports the causal relations during pre- and post-2008 periods in Panel B and Panel C, respectively. As shown in Panel B, the direction of causality during the pre-2008 period is generally consistent with the relation during the whole sample period. In sharp contrast, the results in Panel C indicate that the causal relationship between the commodity market and the shipping freight market does not hold during the post-2008 period. The collapse of causality can be attributed to the prolonged phenomenon of fleet overcapacity during the period. Following the market meltdown in the second half of 2008, the shipping industry has been beleaguered with overcapacity resulting from exuberant ordering of newbuilding vessels during mid-2000s. Accordingly, the market power of the shipping transportation sector has tilted in favor of shippers, while the freight rates are far discount from the sustainable level.

6. Conclusions

This study investigates the cointegration and lead-lag relations between the prices of major commodities imported into Korea and corresponding shipping freight rates using the VECM framework. The results of cointegration tests suggest the existence of a long-run equilibrium between commodity prices and shipping freight rates. However, the empirical results of Granger causality tests indicate that the direction of causality is affected by the division of shipping transportation sectors. For the carriage of iron ores, there is a uni-directional causality running from the freight rates to commodity prices. Conversely, there is a uni-directional causality running from commodity prices to freight rates in the crude oil tanker sector. The causal relation is bi-directional for the pair of bituminous coal prices and the freight rates for the Panamax P3A route. Despite the existence of a long-run equilibrium and causal relation between prices of raw materials and freight rates, the lead-lag relation holds only during the pre-2008 period. After the shipping market collapse in the second half of 2008, causality between commodity prices and corresponding shipping freight rates becomes vague.

The findings in this study offer several important implications for academia and practitioners. First, this study enriches previous evidence on lead-lag relations in the shipping transportation industry. We find the directional divergence of causality by sub-sector in shipping transportation and the time-varying significance of the lead-lag relation between commodity prices and freight rates, supporting empirical evidence in extant studies (for example, see Hsiao Yao-Jen, Chou Heng-Chih and Wu Chun-Chou, 2014; Kou Ying, Liu Li-Ming and Luo Mei-Feng, 2014). Second, managers of commodity traders, steelmakers, power plants, and oil refineries may be able to take advantage of the information from the lead-lag relation between commodity prices and freight rates in their managerial decision making. Specifically, companies for which the main business lies in iron ore trading and steelmaking can capitalize on information extracted from shipping freight rates in establishing trading strategies and calculating the cost of goods sold, respectively. Third, policymakers in the area

of international trade and consumer prices can also take advantage of information on lead-lag relationships between prices of commodities imported into Korea and the corresponding freight rates. As Korea lacks in natural resources, the country's commodity consumptions for manufacturing and power generation rely on cross-border transactions and, as a consequence, its economy is sensitive to changes in commodity prices. Considering that commodity prices have a critical impact on manufacturing costs for major export items as well as consumer prices, policymakers should take account of movements in freight shipping rates as an import element or a leading indicator of the national economy. Finally, this study provides a fresh view to researchers in the area of international trade for Korea. By and large, the vast majority of academic studies in that field focus on export-related topics such as promoting the exports of small- and medium-sized companies, establishing effective export incentive policies, and exploring new export markets. In stark contrast, this study calls for academic attention to a relatively under-explored research topic of dynamic interrelationships between prices of imported goods and the corresponding freight rates. Therefore, the findings in this study stimulate further research efforts on that subject, and contribute to the expansion of the academic area of study in international trade for Korea.

Despite the important findings in this study, there are still gaps that deserve further research attention. Specifically, it is likely that the import price of individual commodities can vary by country (or even commodity provider). Therefore, findings on the causal relations between the prices of raw materials and freight rates can be further enriched by examining a variety of prices in commodity-exporting countries. In addition, information on freight rates of Korea-specific seaborne import routes can be useful for further investigation. In this regard, the attempt to develop Korea-specific freight rate indexes by the Maritime Exchange Information Center appears desirable.

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