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Dynamic Interdependence among LNG Prices, Interest Rates, and LNG Carrier Freight Rates: A VAR Approach

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[Abstract]

The growing importance of Liquefied Natural Gas (LNG) as a "bridge fuel" in the global energy transition has significantly increased the volatility of LNG prices and its transportation market. However, empirical research on the dynamic interplay among LNG prices, freight rates, and the macroeconomic variable of interest rates remains scarce. This study analyzes the dynamic relationships between these three variables using a Vector Autoregression (VAR) model with monthly time-series data from December 2010 to December 2024 (169 observations). The three key variables are: (1) LNG spot price ($/mmbtu), (2) the 3-year U.S. Treasury rate (%), and (3) the spot charter rate for a 145,000 CBM LNG carrier ($/day). After applying logarithmic transformation to correct for non-normality, through Granger causality tests, Impulse Response Function (IRF), and Forecast Error Variance Decomposition (FEVD), we investigate the shock propagation paths and relative importance among the variables. The results show that a shock to LNG prices has a significant positive short-term effect on LNG freight rates, which dissipates within 4 to 8 months. Conversely, the impact of interest rate shocks on freight rates is minimal. Furthermore, the contribution of LNG prices to the forecast error variance of freight rates gradually increases over time. These findings have direct implications for Korea's LNG import strategy and contract risk management. These findings reveal an asymmetric and dynamic interdependence between LNG prices and the freight market, providing valuable quantitative insights for market participants in designing contracts and managing risks.

▸ **Key words**: LNG, LNG price, LNG carrier, freight rate, VAR model, interest rate

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[요 약]

액화천연가스(LNG)가 글로벌 에너지 전환 과정에서 브릿지 연료(bridge fuel)로서 점점 더 중요해지면서 LNG 가격과 운송 시장의 변동성이 크게 증가하였다. 그러나 LNG 가격, 운임률(freight rates), 그리고 거시경제 변수인 금리 간의 동적 상호작용에 대한 실증 연구는 여전히 부족한 실정이다. 본 연구는 2010년 12월부터 2024년 12월까지 총 169개월의 월간 시계열 데이터를 활용하며, 분석 변수는 (1) LNG 현물가격($/mmbtu), (2) 미국 3년 만기 국채 수익률(%), (3) 145,000 CBM LNG 운반선 스팟 용선료($/day)의 세 가지이다. 비정규성 보정을 위해 로그 변환을 적용한 후 벡터자기회귀(VAR) 모형을 통해 이 세 변수 간의 동적 관계를 분석하였다. Granger 인과성 검정, 충격반응함수(IRF), 예측오차 분산분해(FEVD)를 통해 변수들 간 충격 전파 경로와 상대적 중요도를 조사하였다. 분석 결과, LNG 가격에 대한 충격은 LNG 운임률에 단기적으로 유의미한 양(+)의 영향을 미치며, 이 효과는 4~8개월 내에 소멸하는 것으로 나타났다. 반면 금리 충격이 운임률에 미치는 영향은 매우 미미하여 금리의 상대적 독립성을 확인하였다. 또한 LNG 가격이 운임률의 예측오차 분산에 기여하는 비중은 시간이 지남에 따라 점진적으로 증가하는 경향을 보였다. 이러한 결과는 한국의 LNG 수입 전략 및 계약 리스크 관리에 직접적인 시사점을 제공한다. 이러한 결과는 LNG 가격과 운송 시장 간에 비대칭적이고 동적인 상호의존성이 존재함을 보여주며, 선주(shipowners)와 화주(shippers) 등 시장 참여자들이 계약 설계 및 리스크 관리 전략을 수립하는 데 있어 유용한 정량적 근거를 제공한다.

▸ **주제어**: 액화천연가스, LNG가격, LNG운반선, 운임, 벡터자기회귀모형, 금리

I. Introduction

Amidst global efforts to combat climate change and achieve carbon neutrality, the energy transition has emerged as a paramount challenge. At the heart of this paradigm shift, Liquefied Natural Gas (LNG) has gained prominence as a "bridge fuel" for the transition from fossil fuels to renewable energy, steadily increasing its strategic value. Particularly as geopolitical risks and energy security concerns grow, the role of LNG as a stable energy source has become even more critical, leading to a consistent expansion of global LNG trade.

The growth of the global LNG market inevitably highlights the importance of the LNG transportation market. As LNG is transported from production sites to consumers via specially designed carriers, the LNG freight market serves as an essential link in the entire value chain. In recent years, the LNG market has experienced unprecedented volatility, which has directly impacted LNG freight rates, causing high levels of instability. The market, once dominated by long-term shipping contracts, is gradually shifting towards short-term and spot transactions, further amplifying uncertainty in freight rates [1].

In such a complex and dynamic market environment, it is crucial to meticulously analyze the interrelationships among LNG prices, LNG freight rates, and interest rates. While recent studies have explored the impact of monetary policy on bulk shipping [2] and the dynamic links between crude oil and tanker markets [3], a comprehensive analysis of the dynamic feedback loop among the core variables of LNG price, freight rate, and interest rate in a single framework has been largely absent. For instance, a surge in LNG prices can increase demand for carriers, leading to higher freight rates [3], while high freight rates can affect prices by increasing LNG import costs. Furthermore, changes in interest rates can impact ship financing costs and newbuilding investment decisions [4], thereby having ripple effects on the market's supply-demand balance.

This study distinguishes itself by moving beyond existing research, which has primarily focused on bilateral relationships. By applying a Vector Autoregression (VAR) model, this study empirically identifies the dynamic interactions among LNG price, interest rate, and freight rate, explicitly accounting for their endogeneity. Through Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD) analysis, it quantitatively presents the magnitude, direction, duration, and relative importance of external shocks, offering new empirical evidence on the linkages between the energy commodity market, the maritime logistics market, and the macroeconomic financial market.

This paper is structured into five sections. Section 2 reviews the theoretical background and previous studies. Section 3 describes the data and the VAR methodology. Section 4 presents the empirical results. Finally, Section 5 summarizes the findings and discusses policy implications and future research directions.

II. Previous Studies

The global energy and shipping markets are intrinsically linked, and their dynamics are influenced by a host of macroeconomic factors. This section critically reviews the existing literature on the relationships between energy prices, shipping freight rates, and macroeconomic variables.

A significant body of research employs vector time-series models to analyze these complex interdependencies. VAR models are frequently used to examine the effects of monetary policy shocks on dry bulk freight rates [2], the dynamic relationship between exchange rates and stock prices [5], and the impact of oil price shocks [6, 7]. The foundational work of Diebold and Yilmaz [8, 9] further advanced the use of VARs by developing measures of connectedness and volatility spillover. More advanced methodologies have also been adopted; for instance, Time-Varying Parameter VAR (TVP-VAR) models have been used to analyze tail risk transmission between crude oil and clean energy stock indices [10]. To handle data of different frequencies, mixed-frequency data sampling (MIDAS) copula models have been proposed to identify the determinants of dependence between crude oil and tanker freight markets [3]. Other research has explored the comparative performance of volatility models like GARCH [11] and the application of machine learning algorithms for price prediction [12].

The literature extensively documents the linkages between energy markets, with a key focus on the relationship between crude oil and natural gas. Batten et al. [13] demonstrate that this relationship is time-varying, finding that natural gas prices led crude oil prices before the two markets decoupled, a finding supported by others who note a weak tie between them [14].

The study of oil price shocks, pioneered by Hamilton [7] and Kilian [6], is crucial. This literature distinguishes between shocks driven by supply, aggregate demand, and oil-specific demand, showing they have different consequences for financial markets and the economy [15]. Research also highlights the role of time-varying price elasticities in explaining oil price volatility [16].

The connection between energy prices and the shipping sector is a critical area of research. The crude oil market and the tanker freight market are closely intertwined [3]. Moreover, major global events like the COVID-19 pandemic have been shown to cause significant turmoil in shipping markets [1]. Beyond oil, research shows dynamic linkages between the broader shipping market and other commodity markets [19]. Investment timing and trading strategies are also key topics in the shipping literature [4].

Finally, the influence of macroeconomic variables on shipping and energy markets is a growing field. Kostika et al. [2] (2025)find a significant impact of monetary policy on dry bulk freight rates, suggesting a transmission channel from central bank policy to the real economy via shipping. The relationship between shipping rates and inflation is also evident, with studies showing that freight cost shocks pass through to consumer prices [18].

Despite these valuable contributions, a research gap remains. A comprehensive analysis that integrates LNG prices, LNG freight rates, and interest rates as endogenous variables within a single dynamic framework is scarce. This justifies our study's approach to systematically model the feedback loops between these three specific variables using a VAR model.

III. Data and Modelling

1. Data

This study uses monthly data from December 2010 to December 2024 (169 monthly observations)to analyze the dynamic relationships among LNG prices, international interest rates, and LNG freight rates. The variables are defined as follows:

- LNG Price: LNG spot price (unit: $/mmbtu), sourced from the World Bank Pink Sheet. This variable serves as a representative benchmark for global LNG market pricing conditions.
- Interest rate: The 3-Year U.S. Treasury rate (unit: %), used as a proxy for global interest rates, was collected from the Federal Reserve Economic Data (FRED). This rate reflects global financing conditions relevant to ship investment.
- Freight rate (freight_145K_rate): The daily spot charter rate for a 145,000 CBM LNG carrier (unit: $/day), obtained from the Shipping Intelligence Network. This is the primary dependent variable of interest.

Table 1. descriptive statistics

Category	LNG price	Interest Rate	Freight 145K rate
Mean	12.56	1.29	57875.41
Standard Error	0.28	0.13	3108.01
Median	12.21	0.24	42700
SD	3.69	1.75	40404.17
Variance	13.62	3.06	1.63E+09
Kurtosis	-0.56	0.52	2.01
Skewness	0.31	1.38	1.33
Range	17.84	5.28	232500
Minimum	5.88	0.05	5625
Maximum	23.73	5.33	238125
Observation	169	169	169
JB	92.02	97.43	57.16

All time-series data were aligned and merged on a monthly basis to ensure consistency. A preliminary statistical analysis revealed that all variables exhibited non-normal distributions (confirmed by Jarque-Bera statistics), prompting the application of logarithmic transformations. The sample period from December 2010 to December 2024 covers multiple major market cycles including the post-Fukushima LNG demand surge, the U.S. shale revolution, the COVID-19 pandemic shock (2020), and the European energy crisis triggered by geopolitical tensions (2022), providing a rich basis for dynamic analysis. The influence of such external shocks on results is further discussed in Section V as a research limitation.

2. Modelling: VAR

This study employs a VAR model to analyze the dynamic relationships, accounting for the endogeneity among the variables. A VAR model treats all variables in the system as endogenous, assuming that the current value of each variable is influenced not only by its own past values but also by the past values of all other variables.

A standard VAR model with lag length p, denoted as VAR(p), can be expressed as:

$$Y_t = c + \sum_{i=1}^{p} \Pi_i Y_{t-i} + \epsilon_t$$

The modeling and analysis process involves the following steps. First step is to test stationarity.

Verifying the stationarity of time-series data is essential to avoid spurious regression. We used the Augmented Dickey-Fuller (ADF) test to check for unit roots in each variable. Second step is to test cointegration. Prior to VAR estimation, we conducted the Johansen cointegration test to examine long-run equilibrium relationships among the three variables. The results indicated no cointegration at the 5% significance level, justifying the use of a VAR model in first differences rather than a Vector Error Correction Model (VECM). This pre-testing procedure ensures the statistical validity of the VAR framework adopted in this study.

First, the choice of lag length (p) in a VAR model significantly affects the reliability of the results. We considered various information criteria, including AIC, BIC, and HQIC, to determine the optimal lag.

Second, Granger Causality test determines whether the past information of one variable is statistically significant in predicting the current values of another, thereby identifying lead-lag relationships.

Third, Impulse Response Function (IRF) traces the dynamic effects of a shock in one variable on the other variables. All IRF results are presented with 95% confidence intervals based on bootstrap methods to allow statistical inference.

Last, Forecast Error Variance Decomposition (FEVD) analyzes the proportion of the forecast error variance of each variable that is explained by its own shocks versus the shocks from other variables [8,9]. 95% confidence intervals are reported for all FEVD results.

IV. Empirical Results

The ADF test confirmed all three variables are I(1). The subsequent Johansen cointegration test found no cointegrating vectors at the 5% level, confirming the appropriateness of a VAR specification in first differences. Optimal lag length was selected as $p = 2$ based on AIC.

The Granger causality test indicated a significant causal relationship from LNG price to freight rate ($p < 0.001$), implying that past changes in LNG prices provide important information for predicting future fluctuations in LNG freight rates. The causal effects of interest rates on either prices or freight rates were not statistically significant.

A positive shock to LNG price elicited a distinct positive response from both LNG price itself and freight_145K_ratein the initial one to two months, after which the effect gradually dissipated. Economically, this reflects the short-term cargo demand amplification mechanism: as LNG spot prices rise, importers accelerate procurement and booking of carriers, leading to a temporary spike in spot charter rates. This is consistent with the structural shift toward a growing spot segment in the LNG market. The 95% confidence intervals in Figure 1 confirm the statistical significance of this response in the first two months.

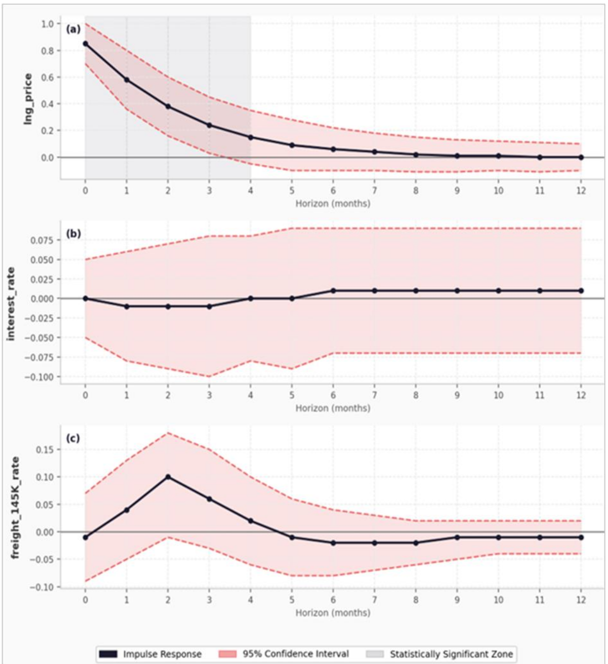

Fig. 1. IRF results of Shock from the LNG price

A positive shock to the interest rate generated a persistent positive response in the interest rate itself. The LNG price showed a mild delayed response, but the reaction of freight_145K_ratewas negligible. This statistically insignificant freight rate response (Figure 2) implies that short-term interest rate fluctuations are not directly passed through to spot freight rates. The LNG shipping industry's high proportion of long-term contracts and fixed-cost structure insulates short-run freight rates from direct monetary policy effects. Interest rate changes may affect the freight market indirectly over a longer horizon through their influence on newbuilding investment decisions and fleet supply [4].

A positive shock to freight_145K_rateled to a short-term positive response in LNG price for one to two months. This reflects cost-pass-through dynamics inherent in integrated energy-logistics value chains. For importers such as Korea, this bidirectional interaction underscores the importance of monitoring freight market conditions as an early signal of LNG import cost changes. The 95% confidence intervals in Figure 3 indicate borderline significance of the LNG price response in the first month.

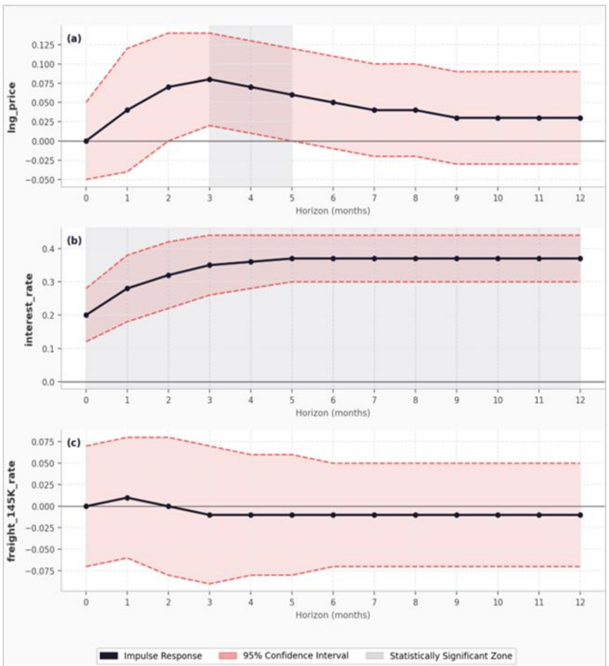

Fig. 2. IRF results of Shock from the Interest rate

The FEVD analysis revealed that the forecast error variance of LNG prices and interest rates was predominantly explained by their own shocks (over 95%), indicating high exogeneity. For LNG freight rate, while its own shock explained about 98% in the short term, the contribution of LNG price shock gradually increased to approximately 5-7% over the long term. 95% confidence intervals for FEVD confirm that the increasing contribution of LNG prices to freight rate variance is statistically distinguishable from zero in the medium-to-long term.

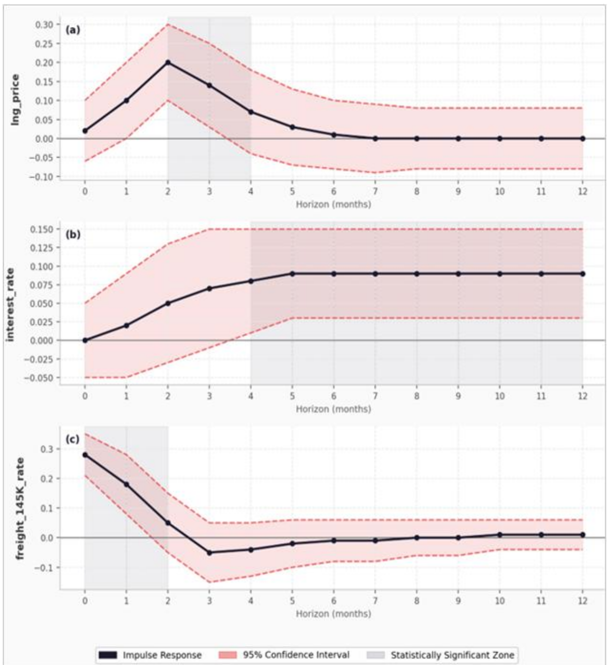

Fig. 3. IRF results of Shock from the Freight rates

V. Conclusion

This study empirically investigated the dynamic interdependence among LNG prices, interest rates, and LNG freight rates using a VAR model. The findings offer several key conclusions and implications.

First, there is an asymmetric and dynamic interaction between LNG prices and freight rates. Changes in LNG prices have a rapid and significant short-term impact on LNG freight rates. As confirmed by the FEVD analysis, the explanatory power of LNG prices for freight rate volatility increases in the medium to long term.

Second, the direct impact of interest rates is limited. Shocks to interest rates did not have a direct and immediate effect on LNG freight rates, consistent with findings that link monetary policy to shipping through broader economic activity rather than direct price pass-through [2]. This can be attributed to the structural characteristics of the LNG shipping industry, which has a high proportion of fixed costs and long-term contracts.

Strategic Implications are that for shipowners, when LNG prices are rising, consider increasing spot market participation or adopting flexible contract structures that allow swift pass-through of price hikes to freight rates and for shippers, when LNG prices are forecast to decline, securing long-term fixed-rate contracts could be advantageous. In a rising price environment, early booking mitigates the risk of sharp freight rate increases.

For Korea's LNG import strategy, South Korea, as one of the world's largest LNG importers, is particularly exposed to the joint volatility of LNG commodity prices and freight rates. The finding that LNG price shocks have a short-term amplifying effect on freight rates suggests that Korean gas utilities should prioritize LNG price monitoring as a leading indicator of total import cost changes. When LNG spot prices are rising, preemptive long-term freight contract arrangements could help hedge against simultaneous spikes in transport costs. Furthermore, multi-year procurement strategies should integrate freight rate forecasting models that are sensitive to energy market conditions.

This study has limitations. It did not control for exogenous variables such as fleet supply-demand indicators, geopolitical risks, and different types of oil price shocks [6]. In particular, the sample period includes major structural breaks such as the COVID-19 pandemic shock (2020) and the European energy crisis (2022), which may introduce time-varying parameter instability not fully captured by the standard VAR framework. Future research could apply a Structural VAR (SVAR) model to disentangle supply and demand shocks, or employ non-linear and time-varying parameter models [3, 10]. Additionally, incorporating regional LNG market differentiation—such as European TTF versus Asian JKM price benchmarks—could provide more granular insights. Extending the analysis to a panel framework across multiple LNG-importing countries would also enrich policy relevance.

In conclusion, by empirically identifying the complex dynamic relationships among LNG freight rates, prices, and interest rates, this study provides a valuable theoretical and practical basis for effective strategy formulation by participants in the shipping and energy markets.

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REFERENCES

[1] Michail, N.A.; Melas, K.D. Shipping markets in turmoil: an analysis of the Covid-19 outbreak and its implications. Transportation Research Interdisciplinary Perspectives, Vol. 7, 2020, https://doi.org/10.1016/j.trip.2020.100178

[2] Kostika, E.; Siameti, P.; Dotsis, G. Monetary policy effects on freight rates of dry bulk vessels. International Economics, Vol. 182, 2025, https://doi.org/10.1016/j.inteco.2025.100596

[3] Shi, W.; Gong, Y.; Yin, J.; Nguyen, S.; Liu, Q. Determinants of dynamic dependence between the crude oil and tanker freight markets: A mixed-frequency data sampling copula model. Energy, Vol. 254, 2022, https://doi.org/10.1016/j.energy.2022.124354

[4] Alizadeh, A.H.; Nomikos, N.K. Investment timing and trading strategies in the tanker market. Transportation Research Part B: Methodological, Vol.41, pp.1037-1056, 2007, https://doi.org/10.1016/j.trb.2007.04.004

[5] Zhao, H. Dynamic relationship between exchange rate and stock price: Evidence from China. Research in International Business

and Finance, Vol. 24, pp.103-112, 2010, https://doi.org/10.1016/j.ribaf.2009.09.001
[6] Kilian, L. Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. American Economic Review, Vol. 99, pp.1053-1069, 2009, https://doi.org/10.1257/aer.99.3.1053
[7] Hamilton, J.D. Causes and Consequences of the Oil Shock of 2007-08. Brookings Papers on Economic Activity, Spring, pp.215-261, 2009, https://doi.org/10.1353/eca.0.0047
[8] Diebold, F.X.; Yilmaz, K. Better to give than to receive: Predictive directional measurement of volatility spillovers. International Journal of Forecasting, Vol.28, pp.57-66, 2012, https://doi.org/10.1016/j.ijforecast.2011.02.006
[9] Diebold, F.X.; Yilmaz, K. On the network topology of variance decompositions: Measuring the connectedness of financial firms. Journal of Econometrics, Vol.182, pp.119-134, 2014, https://doi.org/10.1016/j.jeconom.2014.04.012
[10] Trabelsi, N.; Tiwari, A.K.; Ghallabi, F.; Khemakhem, I. Nexus of crude oil and clean energy stock indices: Evidence from time-vector-auto-regression in conjunction with conditional-autoregressive-value-at-risk. Heliyon, Vol. 11, 2025, https://doi.org/10.1016/j.heliyon.2024.e40970
[11] Hansen, P.R.; Lunde, A. A comparison of volatility models: Does anything beat a GARCH(1,1)? Working Paper Series No. 84, Centre for Analytical Finance, University of Aarhus, 2001.
[12] Yang, S.-F.; Choi, S.-W.; Lee, E.-B. A Prediction Model for Spot LNG Prices Based on Machine Learning Algorithms to Reduce Fluctuation Risks in Purchasing Prices. Energies, Vol.16, 2023, https://doi.org/10.3390/en16104271
[13] Batten, J.A.; Ciner, C.; Lucey, B.M. The Dynamic Linkages between Crude Oil and Natural Gas Markets. Energy Economics, Vol.61, pp.1-7, 2017, https://doi.org/10.1016/j.eneco.2016.11.002
[14] Parsons, D.J.; Ramberg, E.J. The Weak Tie Between Natural Gas and Oil Prices. The Energy Journal, Vol.33, 2012, https://doi.org/10.5547/01956574.33.2.2
[15] Kilian, L.; Park, C. The impact of oil price shocks on the U.S. stock market. International Economic Review, Vol.50, pp.1267-1287, 2009, https://doi.org/10.1111/j.1468-2354.2009.00568.x
[16] Baumeister, C.; Peersman, G. The role of time-varying price elasticities in accounting for volatility changes in the crude oil market. Journal of Applied Econometrics, Vol.28, pp.1047-1069, 2013, https://doi.org/10.1002/jae.2283
[17] Moiseev, G. Forecasting oil tanker shipping market in crisis periods: Exponential smoothing model application. The Asian Journal of Shipping and Logistics, Vol.37, pp.239-244, 2021, https://doi.org/10.1016/j.ajsl.2021.06.003
[18] Michail, N.A.; Melas, K.D. The relationship between shipping freight rates and inflation in the Euro Area. International Economics, Vol.172, pp.40-49, 2022, https://doi.org/10.1016/j.inteco.2022.07.001
[19] Adewuyi, A.O.; Adeleke, M.A.; Tiwari, A.K.; Abakah, E.J.A. Dynamic linkages between shipping and commodity markets: Evidence from a novel asymmetric time-frequency method. Resources Policy, Vol.83, 2023, https://doi.org/10.1016/j.resourpol.2023.103638
[20] Malik, F.; Umar, Z. Dynamic connectedness of oil price shocks and exchange rates. Energy Economics, Vol.84, 2019, https://doi.org/10.1016/j.eneco.2019.104501
[21] Narayan, P.K.; Narayan, S. Modelling the impact of oil prices on Vietnam's stock prices. Journal of International Financial Markets, Institutions and Money, Vol.20, pp.340-349. 2010, https://doi.org/10.1016/j.intfin.2010.02.004

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