A Supply Chain Network Analysis of Energy Cost Propagation in Japan

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The primary energy prices of crude oil, coal, and natural gas increased by more than 100% in Japan between 2015 and 2023. Japan, with limited natural resources, relies on imported resources for over 95% of its domestic primary energy needs. Consequently, Japan is highly vulnerable to price increases in imported energy resources. As a result, the Japanese economy has experienced a rapid increase in energy prices due to insecurity in the global energy supply.

The average prices of imported crude oil, coal, and natural gas in Japan increased significantly by 173%, 316%, and 129%, respectively, during the period from 2015 to 2022. A rapid increase in energy prices significantly affects the production costs of a wide variety of industries. This is because they directly and indirectly utilize primary energy sources such as crude oil, coal, and natural gas within their product supply chains. Additionally, commodity prices rise due to inter-industry cost pass-through processes.

A crucial research question is how to identify the most vulnerable industries and supply chains in Japan affected by the recent energy price shock during the study period from 2015 to 2022. To address this research question, we focused on a cost pass-through network structure that explains how a business entity changes the price of its own commodity in response to an energy price shock. The novelty of this study lies in three aspects. First, this study follows the backward-type unit structure model (see, e.g., Ozaki, 1980; Kagawa et al., 2013) and introduces a new forward-type unit structure model that utilizes the input-output price model, known as the forward-type input-output model. This forward-type model enables us to formulate a unit structure depicting direct and indirect inter-industry cost pass-through processes. Second, this study is the first attempt to quantify the impact of the surge in primary energy prices for crude oil, coal, and natural gas during the study period using the Leontief input-output price model. Based on the forward-type unit structure model, we further identified industries and supply chains facing greater pressure from cost increases due to current energy price hikes. Third, we conducted cluster analysis on the estimated unit structures and clarified several clusters (i.e., appropriate policy targets) as hotspots of the cost propagation.

This study utilized a time series dataset for the imported primary energy prices of crude oil, coal, and natural gas to calculate the average price indices of imported primary energy between February 2022 and February 2023, with the reference year of 2015. This study also utilized the input-output table (IOT) with the highest sector resolution, comprising 373 commodity sectors for Japan in the year 2015.

The results show that crude oil-related products, such as â€˜petroleum products (64.7%)â€™ and â€˜basic petrochemicals (22.3%),â€™ construction materials like â€˜paving materials (19.9%)â€™ and â€˜crushed stones (8.9%),â€™ and transportation services such as â€˜air transport (9.6%),â€™ experienced substantial price-increasing effects when the imported crude oil price rose during the study period from 2015 to 2022. Based on the forward-type unit structure analysis, we further found that â€˜basic petrochemicalsâ€™ and â€˜paving materialsâ€™ played a crucial role as hub sectors with larger cost pass-through in the supply chain networks. In addition, there were significant price increases in â€˜coal products (254.8%),â€™ â€˜electric power generation for domestic use (67.2%),â€™ â€˜cement (47.7%),â€™ and â€˜iron casting (33.8%)â€™ during a rise in imported coal prices throughout the study period. On the other hand, price hikes in â€˜production

and distribution of gas (56.1%)â€™ and â€˜commercial electric power generation (30.5%)â€™ were substantial during an increase in imported natural gas prices. The industry cluster analysis revealed the iron and steel-related cluster as a strongly-connected cluster with significant cost propagation for all three energy resources: crude oil, coal, and natural gas.

One of the most significant findings is that upstream and midstream industries in crucial supply chains bear cost burdens without receiving financial support. Consequently, the Japanese government should implement policies to provide financial assistance to the most vulnerable industries and supply chains, including petrochemicals, road paving, cement, iron and steel, and domestic electric power generation. Importantly, we recommend that the Japanese government increase investments in greener technology to reduce dependence on fossil fuels in the identified vulnerable industries and supply chain paths outlined in this study.