Environmental Consequences in the Lifecycle Change of Container Vessels

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In response to global efforts to reduce CO2 emissions, the International Maritime Organization revised its greenhouse gas reduction target in 2023. The new goal aims for at least a 70% reduction by 2040 compared to 2008 levels. This target is so ambitious that the current energy efficiency regulations in force have inadequate reduction potential. Consequently, zero-emission vessels using alternative fuels are gaining attention as key contributors to achieving this reduction target.

Previous studies suggested the introduction of zero-emission vessels as soon as possible. However, literature on lifecycle assessment (LCA) has confirmed that a longer lifetime of durable goods contributes to reducing lifecycle CO2 (LCCO2) emissions. The extended lifetime involves an environmental trade-off, resulting in increased CO2 emissions during the use phase but decreased emissions in the manufacturing phase.

To ensure sustainable development in international shipping, the trade-off resulting from the introduction of zero-emission vessels must be analyzed. Therefore, this study addresses an important research question: whether the longer lifetime of vessels contributes to reducing LCCO2. The study aims to answer this question and propose decarbonization policies concerning lifetime changes.

Although estimating the LCCO2 of vessels during their lifetime is necessary, the average lifetime of vessels was not statistically specified. The novelties of this study are twofold. First, it identifies the lifetime distribution of container ships, contributing to advancing LCA research on ships that typically assumes an average lifetime as a fixed value. Moreover, this identification model is applicable to other ship types as well. Second, the study empirically investigates the impact of lifetime extension of ships on LCCO2. This demonstration supports decision-makers in developing decarbonization policies concerning the lifetime of ships.

Specifically, the study initially estimates the average lifetime of conventional vessels using maximum likelihood methods and Akaikeâ€™s Information Criterion. Additionally, by varying the lifetime from -10 years to +10 years, LCCO2 emissions in 2040 are estimated using a stock-flow model. Based on the results of LCCO2 estimation, the impact of changing the duration of vessel use on LCCO2 is analyzed. The LCCO2 includes CO2 emissions from both the manufacturing and use phases. Manufacturing emissions, consisting of direct and indirect emissions, are estimated through environmentally-extended input-output analysis. It should be noted that this study focuses on container vessels because container shipping emits the largest amount of CO2 emissions from international shipping.

This study utilized the following data: Sea-web data from IHS Markit includes information on the year each ship was built and retired. Consequently, this study uses Sea-web data to apply maximum likelihood methods and the stock-flow model for estimating the average lifetime of container vessels and the total stock of vessels for each year, respectively. Additionally, the data of embodied CO2 emission intensity of container ships are obtained from â€˜Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID)â€™. The producerâ€™s price data for an average conventional container ship is acquired from â€˜Survey on Shipbuilding and Engineeringâ€™ in Japan.

The results indicate that the average lifetime of conventional container vessels is 23.97 years. This result verifies that the lifetime assumptions in existing studies (ranging from 20 to 26 years) are mostly reasonable. Based on the results of LCCO2 calculation with variations in the lifetime from -10 years to +10 years, this study reveals that shortening the lifetime can effectively reduce LCCO2. One contributing factor to this result is that use-phase emissions (213.6 Mt-CO2) are much higher than manufacturing-phase emissions (9.3 Mt-CO2), as observed by comparing the emissions from use and manufacturing phases in 2008.

Furthermore, we set the natural replacement scenario under the specified lifetime distribution and the governmental intervention scenario where the government forces shipping companies to replace older vessels aged 24 years and more with new container vessels. A comparison between the LCCO2 emissions under the natural replacement scenario and the governmental intervention scenario shows that the governmental intervention can enhance the CO2 reduction effect of energy efficiency regulations by up to 15%. Furthermore, the environmental benefits through governmental intervention become more significant as the energy efficiency regulations get stricter.

In conclusion, this study confirms that accelerating the replacement cycle (i.e., setting the maximum value of operational years) and implementing stronger energy efficiency regulations would have a synergistic effect, highlighting the importance of lifetime policies.