CO2 Emission Reduction Potential in Modal Shifts of Freight Transport in Japan: Multi-regional Input-Output Approach

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In 2022, the transportation sector accounted for 18.5% of Japanâ€™s total CO2 emissions, with trucks contributing 38.0% of the transportation sectorâ€™s emissions. The Japanese government has set a target to reduce CO2 emissions from the transportation sector by 35% by 2030, compared to 2013 levels, making urgent measures in the freight transport industry essential. In terms of environmental impact by transport mode, CO2 emissions per ton-kilometer of transport activity were 208 g-CO2/ton-km for commercial trucks, while ships and railways had significantly lower emissions at 43 g-CO2/ton-km and 20 g-CO2/ton-km, respectively. This highlights the potential for modal shiftâ€”the transition from road transport to maritime and rail transportâ€”as a key strategy for reducing CO2 emissions.

This study provides new insights in two key aspects. First, we constructed a multi-regional input-output (MRIO) table for 2015 by extending the single-region input-output (SRIO) tables of Japanâ€™s 47 prefectures to estimate transport-derived COâ„‚ emissions. While Hasegawa et al. (2015) previously estimated an MRIO for the 47 prefectures in 2005 using the RAS method, data limitations led to rough estimations based on the strong assumption of the location quotient method. It is important to note that the location quotient method used for estimating the MRIO table conventionally determines intra- and inter-regional flows of a specific commodity based on the market share of that commodity produced in different regions. If a purchaser of a homogeneous commodity produced in multiple regions is equidistant from those regions, the regional market shares of the commodity play a crucial role in determining the amount of intra- and inter-regional flows. However, this is a very specific case. In reality, the geographical distance between purchasers and producers is a crucial factor in determining intra- and inter-regional commodity flows between them.

In contrast, this study estimated an initial multi-regional input-output table for Japan in 2015 based on intra- and inter-regional trade coefficients of commodities. These coefficients were estimated using the location quotient method and derived from â€˜actualâ€™ intra- and inter-prefectural freight movements by transport mode, thereby improving the estimation accuracy of intra- and inter-prefectural commodity flows provided by the Ministry of Land, Infrastructure, Transport and Tourismâ€™s freight flow survey data. The initial multi-regional input-output table was then applied to the GRAS method, resulting in a multi-regional input-output table with a balanced demand and supply of commodities.

Second, our analysis comprehensively estimates CO2 emissions by transport mode across all inter-prefectural freight movements, categorizing emissions by commodity type. Previous studies such as Yun et al. (2005), Wisetjindawat et al. (2015) and Matsuo and Hukuda (1997) primarily targeted specific regions within Japan and did not sufficiently consider constraints on transport mode selection or detailed commodity-specific analyses. Given that dominant transport modes and inter-prefectural trade relationships vary due to geographical factors, and that some commodities require the flexibility of truck transport while others can be efficiently shifted to alternative transport modes, our study identifies commodities with the highest potential for CO2 reduction through modal shift.

Our analysis indicates that Japanâ€™s dominant freight transport modes are trucks and ships. If all

truck transport over distances of 500 km or more were replaced by maritime transport, CO2 emissions would be reduced by approximately 24%. Specifically, CO2 emissions from truck transport would decrease by around 33%, while emissions from maritime transport would increase by about 27% due to the shift. Analyzing CO2 emissions by inter-prefectural transport corridors, Tokyo, Hokkaido, Saitama, and Fukuoka were identified as key regions where prioritizing modal shift could maximize CO2 reduction.

Further, among the top six commodities accounting for approximately 20% of total freight transport, four categoriesâ€”daily necessities (such as office supplies and furniture and decorations), chemical products (including petroleum and coal), and other transportation equipment and repairsâ€”were identified as key targets for modal shift. Shifting these commodities from trucks to ships could achieve nearly 60% of the CO2 reduction potential from a complete truck-to-ship modal shift.

As a policy recommendation, we propose providing financial incentives, such as subsidies, to prioritize modal shift in prefectures and for commodities with high CO2 emissions, thereby promoting a more efficient and effective transition toward decarbonization in the transportation sector.