

## **CO<sub>2</sub>, Emissions from Long-Term Post-Disaster Population Displacement: An Environmentally Extended Input-Output Analysis of Fukushima Evacuees**

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The Great East Japan Earthquake of March 11, 2011, triggered large-scale and prolonged population displacement in Japan. In addition to the direct impacts of the earthquake and tsunami, the nuclear power plant accident forced many residents in and around Fukushima Prefecture to evacuate. Although evacuation orders have gradually been lifted, return migration has not progressed smoothly, and for many households<sup>TM</sup> evacuation has evolved into a long-term mode of living. Such sustained population movement has implications not only for social and economic conditions but also for regional environmental impacts.

Changes in population distribution and household composition influence energy demand and associated carbon dioxide (CO<sub>2</sub>) emissions. While previous studies have extensively examined the socioeconomic consequences of post-disaster evacuation, considerably less attention has been paid to its environmental implications, particularly the CO<sub>2</sub> emissions induced by evacuee consumption activities. Understanding these effects is essential for designing reconstruction and support policies that are environmentally sustainable as well as socially equitable.

This study contributes to the literature by quantitatively estimating CO<sub>2</sub> emissions attributable to evacuee consumption, conducting a spatially disaggregated analysis across regions and consumption categories, and integrating regional population mobility with environmental assessment to clarify how long-term population displacement following the Great East Japan Earthquake of March 11, 2011 reshaped regional carbon footprints. Specifically, it examines how the spatial redistribution of evacuees influenced regional CO<sub>2</sub> emissions, identifies the consumption categories that contributed most to emission changes in host regions, and evaluates regional differences in per capita CO<sub>2</sub> emissions associated with evacuee consumption.

This study integrates multiple official datasets to estimate CO<sub>2</sub> emissions generated by evacuees from Fukushima Prefecture living outside the prefecture. Specifically, it uses the Environmentally Extended Input Output Database (3EID), the Family Income and Expenditure Survey (Household Accounts for Two-or-More-Person Households) published by the Statistics Bureau of Japan, and data on the number of evacuees by destination prefecture from the Reconstruction Agency.

This approach allows population displacement caused by disaster evacuation to be quantitatively linked with environmental impacts through consumption activities. By relying on environmentally extended input-output data, the estimated CO<sub>2</sub> emissions include not only direct household emissions but also indirect emissions induced throughout production and supply chains. Moreover, conducting the analysis by destination prefecture makes it possible to examine the spatial redistribution of environmental burdens associated with evacuation.

The regional results reveal clear temporal shifts in CO<sub>2</sub> emissions attributable to evacuee consumption. In the immediate post-disaster period, the Tohoku region excluding Fukushima Prefecture recorded the highest total emissions. In subsequent years, however, the Kanto region surpassed Tohoku, reflecting changes in the spatial distribution of evacuees as return migration progressed unevenly across regions.

Analysis by consumption category shows that the utilities sector, particularly electricity, gas, and

water supply, consistently accounts for the largest share of emissions. The high emission intensity of household energy consumption highlights the importance of energy-related measures in mitigating emissions associated with long-term displacement.

Furthermore, prefecture-level comparisons reveal substantial regional heterogeneity in per capita emissions, suggesting that differences in household energy use patterns and infrastructure conditions play an important role in shaping environmental impacts.

Overall, the findings demonstrate that long-term evacuation following large-scale disasters can generate measurable and persistent environmental consequences through shifts in population distribution and consumption structures. These effects are neither spatially uniform nor sectoral homogeneous, underscoring the need to incorporate energy efficiency and low-carbon infrastructure considerations into reconstruction and evacuee-support policies. By integrating regional population dynamics with environmental assessment, this study provides new insights into the environmental dimensions of post-disaster recovery and supports the development of recovery strategies that are both socially resilient and environmentally sustainable.