COMPARING THE ENVIRONMENTAL AND ENERGY KUZNETS CURVE FOR THE CASE OF JAPAN: SPATIAL ECONOMETRIC APPROACH

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Overview

To foster competition and promote renewable energy, Japan fully liberalized its electricity retail market on April 1, 2016. Before this date, the Japanese electricity market was monopolized by ten regional electric companies, including Tokyo Electric Power Company (TEPCO) and Kansai Electric Power Company (KEPCO). Electricity demand data was available only for regions covered by these ten regional monopolies. After 2016, new electric utilities, often provided by Power Producers and Suppliers (PPS), began competing with the traditional monopolies, enabling the availability of electricity demand data at the prefectural level. Not much is known about how these changes in the electricity market have affected the relationship between power demand, CO_2 emissions, and economic growth and thus the objective of this study is to investigate these relationships.

The contribution of this study is threefold. First, it is among the first to examine the impact of economic growth on CO_2 emissions and power demand for Japan using prefectural-level panel data after the electricity liberalization in 2016. Second, the study employs Geographic Information System (GIS) data to account for spatial dependency among Japan's 47 prefectures. To date, no other studies have considered such spatial dependencies at the prefectural level to analyze the relationships among CO_2 emissions, power demand, and economic growth, as prefectural-level power demand data only became available in 2016. Most studies examining the Japanese electricity market have relied on regional data from the ten traditional regions (Nakajima, 2010; Wakiyama and Kuriyama, 2018; Gurriaran et al., 2023; Otsuka, 2023): Hokkaido, Tohoku, Tokyo, Chubu, Kansai, Hokuriku, Chugoku, Shikoku, Kyushu, and Okinawa. Third, this study contributes to the literature on the Environmental Kuznets Curve (EKC) and the Energy Environmental Kuznets Curve (EEKC) by exploring how renewable energy promotion policies may differently influence the EKC and EEKC, using Japan's electricity liberalization policy as a case study.

Methods

The environmental and energy Kuznets hypotheses were tested under the following models based on previous the theory for EKC (Huang et al. 2024) and EEKC (Ozokcu and Ozdemir, 2017):

$$CO_2 = intercept + \beta_1 GPP + \beta_2 GPP^2 + \beta_3 temp + \beta_4 rice + \beta_5 farm + \beta_6 popden + \beta_7 constr + \beta_8 manf \quad (1)$$

$$elec = intercept + \beta_1 GPP + \beta_2 GPP^2 + \beta_3 temp + \beta_4 rice + \beta_5 farm + \beta_6 popden + \beta_7 constr + \beta_8 manf \quad (2)$$

where CO_2 and elec are the dependent variables representing the total annual CO_2 emissions and total power demand for each prefecture. *GPP* denotes the average nominal gross prefectural product, and *temp* is the average annual temperature of each prefecture. *Rice* and *farm* are the areas of land registered as rice fields and areas of farmlands besides rice fields in each prefecture. *Popden* is the prefectural population density, and *constr* and *manuf* are the number of firms categorized as contractors and manufacturers for each prefecture. The data were collected from the homepage of the Statistics Bureau of Japan for the 2016-2021 period.

To consider the effect of spatial dependency, the models were estimated with the spatial autoregressive, spatial lag, and spatial Durbin models.

Results

Before estimating the spatial econometric models, the CO_2 emissions and electricity demand variables were tested for spatial autocorrelation. The results of Moran's I and Geary's C tests indicated significant spatial autocorrelation, highlighting the importance of applying spatial econometric techniques.

The model estimations indicated some dinstinctive results between the EKC and EEKC. In the EKC model, the growth prefectural product (GPP) had a linear negative effect on CO_2 emissions, whereas in the EEKC model, an inverted U-shaped relationthip was observed between GPP and CO_2 emissions. While the average temperature increase positively influenced CO_2 emissions in the EKC model, it had a negative effect on energy demand in the EEKC model. An increase in rice fields raised both CO_2 emissions and energy demand, while other types of farmland resulted in decreases. Finally increases in the number of construction and manufacturing firms tended to decrease both CO_2 emissions and power demand.

Conclusions

The study revealed that after the liberalization of the electricity retail market in Japan, electricity demand tended to follow an inverted U shape with the GPP, suggesting that regional economic growth may have encouraged the adoption of renewable energy. Additionally, improvements in energy efficiency contributed to a gradual reduction in energy demand. This implies that the electricity deregulation policy may have fostered competition among power companies, thereby promoting greater use of renewable energy and improvements in energy efficiency.

On the other hand, the EKC was estimated to follow a linear decreasing trend. This may be because Japan has already passed the turning point at which economic growth begins to reduce CO_2 emissions, and the variation in the downward trend of CO_2 emissions across prefectures was smaller compared to that of energy demand.

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