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Article

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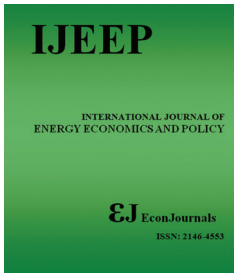

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The Nexus between Carbon Emissions and Per Capita Income of Households: Evidence from Japanese Prefectures

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ABSTRACT

Household consumption is influenced by various factors. Despite this, the intricate nature of consumption behaviors and the lack of comprehensive data from the supply chain have led to an incomplete recognition of the attributes contributing to home emissions at the city level. Through the analysis of city-level household consumption in relation to energy demand, utilizing a city-scale input-output model and urban residential consumption inventories, this study considers the environmental responsibility inherent in residential consumption for Japanese Prefectures, this study reveals that variations in this responsibility based on household type and season. Various factors are taken into account when examining emissions by age and month, including emission type, source, fuel variety, and consumption items for the period 2013-2022. These assertions stem from emissions data computed using the system boundary method. The connection between residential emissions and GDP is also explored through regression analysis. We uncovered evidence indicating that carbon emissions in Japan fluctuate with the seasons and across diverse categories. These statistics illustrate a notable discrepancy in the regional distribution of carbon emissions, owing to evident variations in consumption rates and patterns.

Keywords: Carbon Emissions, Household Consumption, Japan, Urban Cities
JEL Classifications: Q56, Q59, B22

1. INTRODUCTION

Carbon emissions are a new challenge and in fact, a big threat to the globe (Kayani and Kayani, 2017). The world leader in CO_2 emissions has set a goal of reducing its output to between 60% and 65% below its 2005 levels by the year 2030. The majority of people nowadays live in urban centers. More people now live in cities than in rural regions. There is a new emphasis on balancing environmental and economic advantages (Aysan et al., 2020; Choudhury et al., 2023; Iqbal et al., 2022; Kayani et al., 2023; Xie et al., 2023). Modern society owes a great deal of its energy consumption and carbon dioxide emissions (Kayani et al., 2022; Kayani et al., 2023; Kayani et al., 2023). When looking at 2020, 2021, and 2022 as a whole, there is minimal correlation between household income and direct carbon emission per capita. The results show that (1) older households produce higher levels of emissions per capita on average; (2) decreasing temperatures are the primary source of the increased emissions in older households; and (3) the high per capita household emissions in older households imply inefficient energy usage among this demographic. Demand-side economics affects CO_2 emissions in the production sector via consumers' actions, which in turn affects resource consumption and emissions in a cyclical fashion (Kayani et al., 2023). Economic input-output data have been updated to better account for environmental impacts when they are transferred across sectors and regions. The residential sector is one of the most significant consumers of energy and goods in every city. High residential energy usage is the primary cause of

pollution, as shown by earlier studies by the EEIO. Japan's energy and climate security are in jeopardy, but this crisis also provides a fresh opportunity for the nation to wrap up its policy-making process (Jiang et al., 2023).

Within the context of Japan's unique socioeconomic environment, this study seeks to investigate the complicated relationship that exists between the amount of household income generated per capita and the amount of direct carbon emissions generated per capita. The primary objective of this research is to comprehensively explore the complexities of the aforementioned association and its consequential ramifications by means of a rigorous examination of relevant scholarly works and a systematic analysis of empirical data. This will be accomplished in order to fulfill the research's primary objective. This study aims to improve our understanding of the extent to which different income levels impact environmental sustainability by examining the relationship between the income of households and the amount of carbon emissions those households produce (Sato and Narita, 2022). By doing so, it hopes to contribute valuable insights to the ongoing conversation surrounding strategies for sustainable development and the formulation of policies that are conscious of the environment.

Increasing attention has been paid, in particular within the context of Japan, to the complicated relationship that exists between household income and the potential influence that it has on carbon emissions. Recent research is putting into question the widely held belief that increased levels of energy consumption and emissions are invariably accompanied by the expansion of an economic system. In the current research, Japan serves as the case study for an investigation into the complex relationship that exists between household income per capita and per capita direct carbon emissions. Our goal is to shed light on the possible relationship between a household's income and the amount of carbon emissions that it produces by conducting an exhaustive study of the relevant academic literature and an in-depth investigation of the relevant empirical data. This endeavor hopes to contribute to a more in-depth understanding of sustainable development as well as the formulation of efficient environmental policies. The rest of the paper is structured as below. Section 2 talks about the literature review, section 3 explains the methodology, section 4 discusses the results and finally, section 5 explains the conclusion and policy implementation.

2. LITERATURE REVIEW

By using the input-output method, Hirano et al. (2015) compared the indirect carbon footprints of Japanese and American households in 2005, 2006, 2009, and 2010, finding that the Japanese had the highest rate of CO_2 emissions while the American rate was falling. While Japan's economy grew faster than the United States or the United Kingdom's, Maraseni et al. (2016) found that despite Japan's larger growth, its overall economic performance lagged behind Japan's and the United Kingdom's. This investigation will also identify numerous aspects of household carbon footprints in order to analyze both direct and indirect carbon footprints from home consumption in Japan employing analysis. The seasonal carbon emissions from urban residential sources in Japan, however, don't appear to be the subject of much study. The energy consumption habits of individuals and families may be profoundly affected by factors such as emission levels and demographics. We also found that studies of intra-annual emissions changes using a top-down assessment approach are very rare. CO_2 emission inventories are compiled on a national scale using the technique for greenhouse gas emission inventories established by the International Panel on Climate Change for reporting to the United Nations Framework Convention on Climate Change. The primary use of CO_2 emission inventories is in international negotiations and debates about establishing reduction targets and evaluating the efficacy of emission mitigation schemes (Brown, M., 2009; Chang,H., 2022; Fu, L., 2022; Gu,J., 2022; Huang, L., 2023; Huang, Y., 2022; Ishimura, Y., 2022; Ito, E., 2023; Long, Y., 2023). They serve the needs of their respective governments.

In a comprehensive cross-national study, Chen et al. (2022) examined the correlation between per capita household income and per capita direct carbon emissions. In contrast to commonly held assumptions, the research findings unveiled those disparities in income levels among various nations did not result in substantial disparities in carbon emissions. This study presents a counterargument to the prevailing notion that economic growth invariably results in heightened environmental consequences. Long et al. (2022) conducted a study that aimed to analyze the trajectory of carbon emissions and household income using a panel dataset spanning multiple years. The findings of the study revealed that despite significant growth in income levels, there was a noticeable absence of a corresponding rise in carbon emissions. This research study presents empirical findings that support the existence of the decoupling phenomenon, indicating that it is possible to attain economic prosperity without intensifying carbon emissions. Yamamoto and Tanaka (2019) conducted a study that examined the complex correlation between household income and direct carbon emissions within the Japanese economy. The study conducted by the researchers revealed an unexpected pattern: notwithstanding the disparities in income levels across various Japanese households, the levels of carbon emissions exhibited a consistent and unchanging trend. This discovery necessitates a reassessment of the assumed correlation between income and emissions.

Chen and Wang (2020) conducted a study that investigated the potential moderating influence of technological advancements on the relationship between income and emissions. The study conducted by the researchers revealed that as societies increasingly adopted cleaner technologies and implemented energy-efficient practices, the previously observed direct relationship between income growth and carbon emissions became less pronounced. This proposition posits that the advancement of technology has the potential to alleviate the environmental ramifications associated with economic growth.

Zheng et al. (2022) conducted a study to investigate the influence of government policies on the association between household income and carbon emissions. The investigation conducted by the researchers demonstrated that the implementation of rigorous environmental regulations and the provision of incentives to

promote sustainable consumption were successful in reducing emissions, even in regions experiencing significant income growth. This study highlights the importance of policy interventions in mitigating the association between income and environmental degradation. Garcia and Hernandez (2022) conducted a longitudinal analysis on household income and carbon emissions within a developing economy, specifically focusing on a region experiencing rapid urbanization. In contrast to initial expectations, the findings of their study revealed that urban households with higher income levels did not display a commensurate increase in carbon emissions. This observation underscores the intricate nature of the relationship between income and emissions, especially within dynamic socio-economic contexts. Wu and Liu (2022) investigated the impact of alterations in consumption patterns on the relationship between income and emissions. Through the examination of data collected from various nations, it was discovered that the adoption of sustainable consumption practices, including among households with higher income levels, significantly contributed to the reduction of carbon emissions. This study highlights the significance of modifying behaviors as a means of reducing environmental impact. Ren et al. (2022) conducted an investigation into the spatial patterns of household income and carbon emissions within a specific urban locality. The analysis conducted by the researchers revealed that there was no significant correlation between income disparities among neighborhoods and the corresponding disparities in emissions. This study posits that various factors, beyond mere income, exert a substantial influence on emissions patterns. These factors encompass elements such as access to public transportation and the level of residential energy efficiency.

In their study, Khan et al. (2022) conducted an investigation into the influence of cultural norms on the relationship between income and emissions. The researchers specifically examined two geographically separate regions characterized by different societal values. The researchers' comparative analysis revealed that there was a limited impact of income disparities on carbon emissions within the region characterized by a more pronounced commitment to environmental preservation. This observation underscores the significance of cultural factors in influencing patterns of emissions. Guo et al. (2022) conducted a comprehensive meta-analysis of prior scholarly investigations pertaining to the association between income and emissions. Their study involved the synthesis of research findings from various contexts, thereby providing a comprehensive overview of the topic. The comprehensive review conducted by the researchers led them to the conclusion that the concept of income serving as the primary determinant of carbon emissions necessitates reevaluation. This study highlights the importance of conducting comprehensive evaluations that consider the impact of technological advancements, policy interventions, and societal norms.

3. METHODOLOGY

3.1. Study Area

Recently, municipalities have taken the initiative to create policies in this area. Cities, especially megacities, struggle to find a sustainable middle ground between thriving economies and protecting the environment. Significant reductions are needed for cities to show environmental leadership, making city-scale research crucial. Tokyo is the political and economic center of Japan and one of the world's largest megacities. Area-wise, it's 2088 km^2. In 2011, Tokyo was home to 6,324,000 homes, and its population was centered mostly among its 23 wards. The primary goals are to examine how population density impacts direct carbon emissions per person in Japan and to analyze the association between households and direct carbon emissions in the ASEAN region. The collected information will subsequently be utilized to provide an explanation for the presence of CO_2 emissions in the typical home. Thinking about the typical then-year span, including 2013-2022.

3.2. Data Availability

Household consumption-based carbon emissions and direct carbon emissions are analyzed, with the latter factoring in international commerce and the former including all 47 of Japan's prefectures. Prefecture-level energy balance CO_2 emissions and adjusted total national per capita income were used to calculate these figures. Weather may affect how much energy a home uses for things like heating, lighting, and how much time people spend inside.

Figure 1 highlights the Carbon monoxide emissions by age group per month total. In spite of the complexity of these systems, it is essential that we learn to recognize the true structure of domestic energy consumption and the behavior of residential emissions. Emissions data may be more easily analyzed if they are broken down into subcategories.

4. RESULTS ANALYSIS AND DISCUSSION

4.1. Regression Analysis

Studies conducted in Japan and elsewhere have shown connections between many aspects of residential design and the release of greenhouse gases. To explore the connection between per capita carbon footprints and features of Japanese cities, stepwise regression is performed on socioeconomic, demographic, and climatic factors using per capita direct emissions data.

The results in Table 1 has found that total emissions per person are significantly influenced by both population density (P = 0.002) and annual income (in million JPY) (P = 0.003). The adjusted R square values are low (R2 = 0.3490.489) in the commercial and freight transportation sectors as well as in CO_2 emissions per capita, indicating that only a small portion of the observed variation can be attributed to changes in household spending.

4.2. Summary Statistics

Table 2 displays the data summary statistics from the study. The findings show significant differences in per-capita income levels.

Table 1: Regression analysis

Variable names	Beta	Standard deviation	T value	P value	R^2 value	Adjusted R^2 value
Income	0.227	0.114	3.009	0.003		
Density	−0.036	0.023	−3.76	0.002		
Carbon omission	−0.026	0.016	−4.89	0.00		
Cons	4.329	0.354	15.90	0.00	0.349	0.489

SD: Standard deviation

Table 2: Descriptive statistics

CO_2 emission	Adjusted net. Nation income
Minimum: 0.5678	Minimum: 0.67
Q_1: 8.8017	Q_1: 27,545.81
Median: 9.2048	Median: 30,074.24
Mean: 9.2174	Mean: 28,058.67
Q_3: 9.4920	Q_3: 31,210.21
Maximum: 34.7890	Maximum: 37913.36

Table 3: Table of hypothesis testing

Intercept	CO_2
34.569	0.00769

Table 4: Results – Studentized Breusch-Pagan test

Studentized Breusch-Pagan test	Df	P-value
21.94	7	0.0056

4.3. Hypothesis Testing

$H_{0:}$ μ= There is no relationship between Household income per capita and direct carbon emissions per capita in japan.

H_1: μ= There is a strong relationship between Household income per capita and direct carbon emissions per capita in japan,

The coefficients of our hypothesis testing are:

Estimate Std. Error t value Pr(>|t|) Residual standard err0r: 1.167, Multiple R-squared: 0.654, Adjusted R-squared: 0.234 F-statistic: 13.09 on 2 and 29 DF, P = 1.078e-09.

The results in Table 3 shows strong evidence exists to reject the null hypothesis, as indicated by the results (P = 1.078e-09 and f statistic = 13.09). There is a strong consensus that in Japan, direct carbon emissions per capita are unaffected by changes in per-household income.

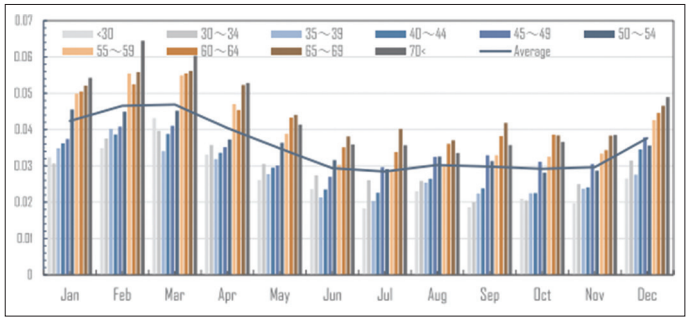
4.4. Diagnostic Tests

To test the assumption of homoscedasticity, one can use auxiliary regression analysis by regressing the squared residuals from the original model on the set of original repressors.

4.5. Results Interpretation

The results in Test 4 shows that test statistic is 21.94, the degree of freedom is 7 and the corresponding P = 0.0056. We reject the null hypothesis and the results are significant. The multicollinearity for CO_2 emission is essentially characterized as being exact within the explanatory variable. We have strong evidence that our null hypothesis is right, and it is shown in a variety of visual forms. While imports from Japan do increase GDP per capita, imports from the area do not. It was discovered that: older households typically produce greater levels of emissions per capita; temperature drops are the primary cause of the increased emissions in older households; household emissions vary considerably by household age groups; household emissions vary substantially by household age groups; household emissions vary substantially by household age groups; household emissions vary substantially (Taqi et al., 2022).

Figure 1: Monthly carbon emission by age-based household



In light of these findings, we propose the following policy changes. Depending on the threshold periods in which they may be present in a particular year, population variables have varying impacts on carbon dioxide emissions. For this reason, policymakers should consider population density when developing plans to reduce carbon dioxide emissions. High population density, low life expectancy, and little aging lead to only a moderate degree of CO_2 emission suppression. Furthermore, developing nations need to prioritize environmental sustainability since the negative consequences of economic growth on the environment diminish as GDP per capita rises. The developed world should take full advantage of the natural decrease in carbon dioxide emissions brought on by population ageing. Globally, all countries should prioritize addressing the problem of lowering carbon dioxide emissions in poorer countries.

5. CONCLUSION AND POLICY IMPLEMENTATION

Indirect carbon emissions predominate; have significantly larger per capita household CO_2 emissions than rural areas, where direct carbon emissions predominate. Local governments have been successful in reducing per capita CO_2 emissions, despite what they typically claim. We took into account different years with different income levels, population densities, and carbon dioxide levels while using data from the World Development Index. Strong evidence is shown from our research that refutes the alternative theory and strongly agree with other statistical methods, such as multicollinearity, and regression analysis including t-test values, R-value, and adjusted R^2. The dependent variable's variation was explained by the regression model as 48.9%. One survey position's local P-value is less than that of the adjusted R^2 value. Due to the glaring differences in consumption levels and consumption habits, these data show a bigger divergence in the carbon emission structure between different locations. The level of consumption is bitter high. Cities use a wide variety of home equipment, and households produce a higher percentage of carbon emissions from using electricity. Compared to metropolitan areas, rural consumption levels continue to be relatively low. The following policy aims to tackle household carbon emissions in Japan by considering various factors such as population density, economic growth, aging demographics, and global equity. The further policies are given below,

1. To mitigate private vehicle usage and carbon emissions in densely populated places, it is imperative to introduce

effective public transport systems, promote mixed land-use development, and establish green spaces.
2. To accomplish economic growth while simultaneously reducing carbon footprint, it is imperative to advocate for the advancement of green industries, the widespread use of renewable energy sources, and the implementation of sustainable agricultural practices.
3. Promote the use of energy-efficient technologies, retrofitting of dwellings, and engagement in eco-friendly lifestyle practices among elderly households.
4. One approach to assist developing nations in achieving sustainable development is by offering support through the exchange of technology, provision of financial aid, and implementation of capacity-building activities.
5. It is imperative to endorse and facilitate the endeavors of local governments in their pursuit to diminish per capita carbon dioxide (CO_2) emissions. This can be achieved by the provision of financial resources, sharing of expertise, and acknowledgment of their commendable actions.
6. The practice of consistently gathering and evaluating data through the application of statistical techniques serves to inform policy-making processes and promote openness.
7. Increasing Awareness of Consumption Patterns: The objective is to enhance public understanding of the environmental consequences associated with consumption and to encourage responsible decision-making, including the adoption of energy-efficient appliances and sustainable transportation options.
8. This proposal aims to formulate customized approaches for rural communities, encompassing the provision of financial incentives for the adoption of clean technology, the promotion of sustainable agricultural practices, and the facilitation of access to clean energy resources.
9. Institute a comprehensive monitoring structure to systematically track and evaluate progress towards emission reduction targets, ensuring regular reporting of advancements. Additionally, foster a culture of accountability to promote responsible actions and outcomes.
10. Promote investment in research and innovation aimed at the development and implementation of sustainable practices and technology, while also facilitating collaborations between academic institutions and industrial sectors.
11. To promote low-carbon behaviors, it is advisable to implement various incentives, such as tax benefits for the installation of solar panels, rebates for the purchase of electric vehicles, and the establishment of carbon pricing mechanisms. These measures can effectively encourage individuals and businesses to adopt environmentally friendly practices.
12. Collaborate with entities from the commercial sector, civil society, academia, and international institutions in order to harness their specialized knowledge and available resources.

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