Journal of Economics, Management & Business Administration (JEMBA)

Volume 1, Number 2, 2022, Pages 15 – 26

Journal Home Page

https://journals.irapa.org/index.php/jemss/

# Nexus between Carbon emission per capita and Urbanization

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**ARTICLE INFO**

***Article History:***

| | | |
|---|---|---|
| Received: | July | 10, 2022 |
| Revised: | August | 25,2022 |
| Accepted: | September | 15,2022 |
| Available Online: | October | 15,2022 |

***Keywords:***

*CO2 Emission, Urbanization, GDP.*

***JEL Classification Codes:***
H10, H10, H8, O1,P0

## ABSTRACT

*The effects of urbanization on global warming are substantial. Several carbon accounting methods have been proposed to identify which municipalities should make mitigation efforts, but none of them have gained widespread acceptance. Six major cities in Japan are chosen, and their per capita CO2 emissions between 1982 and 2021 are identified and compared using a method based on four system boundaries. The overall rate of increase in CO2 emissions from the transportation sector was 9% per year between 1990 and 2008, and the rate of increase in CO2 emissions from road transportation alone was even higher at 2.6% per year. According to Stern's 2007 prediction, global transportation-related CO2 emissions will more than triple by 2050. According to the results, there are the relationships within geographical indicators of urban form and sectorial CO2 emissions for both the passenger and residential transportation sectors.*



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## INTRODUCTION

The living level for Japanese has increased which increase the economic level of the country the economic level of Japanese raised from 1479 to 1997 to 21,559 RMB in 2019, the rate of consumer raised the expenditure of Japanese and average growth rate is more than 12.5 percent. The urbanization level of Japanese for living also increased very rapidly from 19.39% in 1980 to 58.52% in 2017. As it turns out (National Bureau of Statistics, 2019). Carbon emissions in Japan are predicted to rise between 2017 and 2021 as the country continues to urbanise and its economy expands. Wei et al. (2007) report that in metropolitan areas, the yearly standard of using coal increased by the rate of 1085 kg In addition, around 80% of the energy is used for final consumption and economic activity.

According to statistics, the United States is responsible for 80% of all $CO_2$ emissions, while the United Kingdom is responsible for around 74%. Hertwich and Peters (2009); Bin and Dowla tabadi (2005). In order to study about the climate change the characteristics about emission of carbon dioxide conveyed us about driving force. The carbon foot print provide both the direct and indirect carbon dioxide emissions from the domestic consumption . A lot of academic research done carbon footprint of households use had been done, and according to the input and output approach is used to find out a household's carb0n footprint. Hasegawa et al. (2014 to 2022) search out the aspects home carbon footprint for 48 Japanese cities and search the elements that made contribution in the regional variation. If we study about the trend of their household carbon footprint from 1998 to 2022 according to a temporal perspective, Steenol sen (2015) combined the Norwegian according to the expenditure of consumers survey data according to the global MRIO database, which searched out the information about the transportation, housing, and food in Japanese are the most important driving forces for household carbon footprint raised. In the end, the majority of researchers portrayed their focuses on home carbon footprints at the international and regional levels, but very few researchers analyzed that the changes in household carbon footprints around several nations with a lot of degrees related to developmental growth in Japanese. Using the input-output method, Ma et al. (2015) compared the indirect carbon footprints of Japanese and American households in 2005, 2006, 2009, and 2010, finding that Japan's rate of $CO_2$ emissions was highest and the United States' rate was lowest. While Japan's home carbon footprint was larger than that of the United States and the United Kingdom, it was still less than Japan's and the United States'. This finding was published in 2016 by Maraseni et al. However, there is currently no study comparing the economic development of two nations from the same region whose cultures are comparable, such as Canada and Japan. This study will also identify several aspects of household carbon footprints, which will be useful in studying both direct and indirect carbon footprints from household consumption in Canada and Japan through output analysis. In addition, the elements that contribute to these carbon footprints are unveiled in order to learn more about lowering carbon emissions at home while taking local conditions into account.

Japan's climate change exemplified the most pressing environmental concerns of the twenty-first century, with implications for the capacity of developing countries to sustain rapid economic expansion. Japan's lifestyles have had a significant global influence due to the country's high carbon dioxide emission percentage (72%) in greenhouse gas (GHG) (Majid et al., 2014). To the accountant, consumption-based accounting better depicts the role of carbon dioxide emission in developed nations throughout the supply chain of consumer demand GHG emissions from industry (Peters, 2005). To a greater extent than direct GHG emissions, which in Japan are dependent on home gas and the daily use of autos, indirect GHG emissions have some relation to household consumption, according to studies of consumption-based accounting (Hertwich, 2022). A direct correlation between Japan's carbon dioxide usage and its indirect emissions measures has been found. Scientists have determined directions for future climate change study. It has to absorb plenty of carbon and establish a connection between domestic economic activity and $CO_2$ consumption. The disparity in household $CO_2$ emissions is mostly the result of economic differences across regions of Japan, with HCF inequality serving as the primary cause. The bulk of HCF is produced by a very small percentage of the population (those with higher incomes), whereas the vast majority of people (those with lower incomes) contribute very little to the problem. Justice and justice are crucial aspects in the pace of policy implementation in the process of reducing carbon dioxide emissions and reducing emissions overall. More ever, properly handling carbon had several Development Goals (2015) in Japan, which crucial role in mitigating climate change and lowering the degree of wealth disparity.

Boundary 4 emissions have been rather constant throughout the length of the research period of over 20 years, but per capita emissions have varied widely across the other system borders. This is so despite the fact that these cities differ greatly in terms of their industrial make-up and history, human population, and yearly average temperature. Local governments have been effective in lowering CO2 emissions per inhabitant, contrary to popular opinion. These claims arise from emissions estimates made using system boundary 2 methods. We believe that the system boundary 4 should be adopted by local governments if they are serious about achieving their goals of reducing the impact of urban climate change. This boundary provides a more precise analysis of how urban CO2 emissions and trends are changing over time. The results demonstrate that the shape of the region's CO2 emissions is an inverted-S. Exports as a percentage of GDP are the primary drivers of carbon emissions in developed, emerging, and late-developing ASEAN nations.

The primary goal is to compare and contrast various statistical approaches to carbon dioxide (CO2) emission. Multicollinearity within the explanatory variable may be described in detail. We have significant evidence to reject the alternative theory, as shown through a variety of visual displays. In addition, although Japan's overall imports raise pollution levels, regional imports into Japan actually decrease pollution levels. If you take three distinct years, say 2020, 2021, and 2022, then normalise them all together, you won't see any difference in your direct carbon output per person. The findings indicate that (1) there is a significant difference in emissions produced by households based on age, with older households producing higher levels of emissions per capita; (2) the high per capita household emissions in older populations suggest inefficient energy use among the elderly; (3) the increased emissions in older populations are primarily due to temperature decreases, while in younger populations this is not a significant factor; and (4) the high per capita household emissions in older populations suggest inefficient energy use among the elderly. One of the fastest-growing sectors in CO2 emissions is the transportation sector.

The HCF was profoundly impacted by the fact that various Japanese housing styles had widely varying amounts of household consumption. The study suggests distinguishing between single-person and multi-person households in terms of their daily routines. There is a growing trend of single-person households in Japan, which is mirrored by the country's low marriage rate. The percentage of households comprised of a single individual rose from 27.6% in 2000 to 35.2% in 2018; this trend is expected to continue into the foreseeable future (National Institute of Population & Social Security Research, 2018). HCF's study shows that household spending alone isn't enough to provide a level playing field in terms of economic growth and development amongst nations. To thoroughly understand the features of HCF in light of the increasing influence of household consumption on CO2 emissions in Japan, and to account for the fact that HCF varies significantly across single-person and multi-person homes throughout prefectures.

## LITERATURE REVIEW

Long-term economic development in Japan has been studied and policy decisions have been made in part because of the country's high carbon dioxide consumption in the twenty-first century. Recently, a research on this same subject was released (Fischer et al., 2017). Sustainable home consumption has emerged as a critical component of urban economic growth in light of the rising commercialization of human activities (Elmqvist et al., 2019). The environmental effect of Japan is increasing, according to research by Caeiro et al., Ramos, and Huisingh (2012), particularly in highly populated metropolitan regions. To demonstrate how a change in family behaviour may enhance the long-term survival of the Japanese people's way of life, this article compares the activities of families with varied income levels in Japan. For the sake of the planet and future generations' health, cutting down on energy usage at home is crucial, as Wang et al. (2019) noted. Recent studies have indicated that domestic consumption accounts for a significant portion of global greenhouse gas emissions, making climate change the greatest barrier to global sustainable development (GHGs). Seventy-two percent of the world's GHG emissions are attributed to domestic consumption, according to a study that evaluated GHG emissions tied to final consumption in 73 nations. According to research by Druckman and Jacks0n, more than 75 percent of carbon dioxide emissions in the United Kingdom originate in private homes (2010). Guet al., Sun, and Wennersten (2013) found that the two largest sources of CO2 emissions worldwide are transportation and household energy usage. Lima,

Peru's home energy usage and related greenhouse gas emissions were monitored by Cárdenas-Mamani et al., Kahhat, and Vázquez-Rowe between 2007 and 2015. (2022). The authors argue that low-income families utilise LPG instead of electricity because of its lower cost. Indirect C02 emissions from household consumption have a larger effect than direct C02 emissions, making research on indirect HCF vital. From a consumer lifestyle viewpoint, Wang and Yang (2014) studied indirect C02 emissions from urban and rural Chinese households (CLA). CLA and input-output (IO) studies were used to determine the urban household's indirect CO2 emissions between 2002 and 2012.

(Liu et al., Wang & Wang, 2019) argue that increased family income will lead to a dramatic decrease in indirect CO2 emissions due to lower levels of consumption. We also created an overview of the literature on HCF in Japan, given that nation was the major focus of our study. Despite the country's ageing and shrinking population, Shigetomi et al., Kagawa, and Tsuneo (2014) predicted that Japan's HCF in 2035 would be 4.2% lower than in 2005. After analysing home C02 emissi0ns on the basis of everyday activities, Japanese researchers discovered that, for certain households, indirect C02 emissi0ns have grown more than direct C02 emissions as a result of modern consumption habits. A study by Lng et al., Yshida, and Dng (2017) analysed 49 prefectural capitals in Japan in 2005 to determine indirect HCF by source and the impact of indirect HCF on other variables. When calculating Japan's domestic carbon footprint associated with household spending in 2030, researchers Shigetomi et al., Kagawa, and Tohno (2018) found that a rise in the country's total fertility rate and the proportion of high-income couples had a negative impact on the country's carbon footprint. Huang et al., Chapman, and Matsumoto (2019) analysed the carbon footprint of Japanese homes using an index and a structural comparison analysis of data from 1990 to 2005. There is an estimated yearly increase of 6.6 Mt-CO2 in indirect HCF, or 2.5 times that of direct HCF.

Shigetomi et al., Yamamoto, and Kondo assessed the decline in HCF across all of Japan's prefectures for 25 factors in 2005. These variables were all connected to people's lifestyles and socioeconomic backgrounds (2021). Long et al. (2021) conclude that urban consumption has a proven influence on global greenhouse gas emissions based on an analysis of urban home emissions in 52 major Japanese cities compared to a benchmark of 500 emission categories. In addition to slowing efforts to create a more fair society, economic inequality also plays a role in the development of carbon inequality throughout the climatic transition. Carbon dioxide (CO2) emissions are widely believed to be one of the main causes of climate change. Although it barely accounts for 0.4–0.9% of the Earth's land mass. Most of these pollutants are produced in urban areas (70%+). Because of this, cities play a crucial role in the climate change debate. Because of this, several academic disciplines have investigated how urbanisation affects CO2 output.

## STUDY DESIGN

The primary goals of this study are to provide an explanation for the presence of CO2 emissions and to explore the relationship between trade and the environment across the ASEAN member states.

### Data Availability

Using an MRIO model that takes into account the 47 prefectures of Japan as well as commerce, we evaluate the consumption-based carbon emissions of 60,000 households. Hasegawa et al. provided the MRI0 data table. By correlating each prefecture's official environmental division (see table S1, online at https:// Climate Watch. 2020. GHG Emissions. Japan, DC: World Resources Institute. /ERL/15/114053/mmedia) with prefecture-level energy balance CO2 emissi0n, population density, and adjusted total national per capita income, we were able to collect detailed, industry-level data on each prefecture's direct carbon emissions.

The following is the definition of the consumption-based carbon emission of household **h** in city **k** attributable to prefectures, the test statistics is as foll0ws:

$$F_{jh}^{k} = \sum_{i,r,s} f_i^r L_{ij}^{rs} y_{jh}^{k,\text{NSFIE}} \qquad (1)$$

Whereas **f** refer to factor input, the Leontief inverse of GHG emissions per unit of production. To learn more about how the Leontief demand-pull model is used to find the basic results. $Y_h^{k,NSFIE}$ is c0nsumption expenditure 0f each 0f the 60,000 households in city $k$ rep0rting in the NSFIE, $i$ and $j$ are sect0r 0f 0rigin and destinati0n, and $r$ and $s$ are the exp0rting and imp0rting. We basically used different meth0ds t0 estimate consumpti0n based carb0n emissi0n.

### C0bb–Douglas and Urban Scaling Method:

To ass0ciate the c0bb-dougles meth0ds with urban scale meth0d, may relate the meth0d;

$C \sim p^{beta} = p^{beta1} p^{beta2}$

Where beta is the functi0n of two probabilities of beta's. the cobb-douglas with $beta_1 + beta_2 = 1$

$C \sim P^{\theta} A^{1-\theta}$,

where $\beta_P = \theta$ and $\beta_A = 1 - \theta$. Next, we divide both sides by $A$

$$C/A \sim (P/A)^{\theta}$$

Descriptive statistics are used to summarise a data collection, which may be a representation of the complete population or a subset of it. Metrics for summing up data and gauging its dispersion are the backbone of descriptive statistics (spread). The median and average values in a data collection are the focus of central tendency measurements, whereas the dispersion of the data is the focus of variability measures. To assist individuals understand the relevance of the facts being considered, both technologies use visual aids like graphs and tables and vocal explanations.

It is possible to use statistics to identify which of these variables is more influential. It addresses the questions, "What factors are most important?" Which ones can we ignore? For example, how do the various pieces interact with one another? How sure are we in each of these qualities is the most important question. For the aim of data analysis, we employed several statistical methods, including a regression model, checks for heteroskedasicity and correlation, and a variety of graphical representations, to find that Japan's per-capita wealth had no effect on the country's per-capita emissions of direct carbon. The cobb-douglas and power-law functions were also employed.

**RESULTS DISCUSSION**

**Descriptive Statistics:**

In table 1, 2, Reports the descriptive statistics and the correlation estimate. Based 0n the result of descriptive statistics, provide basic information about the factors, The transportation industry is also regarded as having one of the quickest rates of $CO_2$ emission growth. $\mathbf{Q_1}$, $\mathbf{Q_3}$ represent the upper and lower quartile that anticipated in quartile deviation. Detail of years calculation from R-language as given.

| **CO2 emission** | **Pop. Density** | **Adjusted net. Nation income** |
|---|---|---|
| **Min**: 0.5678<br>$\mathbf{Q_1}$: 8.8017 | **Min** : 0.234<br>$\mathbf{Q_1}$: 347.416 | **Min** : 0.67<br>$\mathbf{Q_1}$:27545.81 |
| **Median** : 9.2048 | **Median** :348.809 | **Median** : 30074.24 |
| **Mean** : 9.2174 | **Mean**: 325.233 | **Mean** : 28058.67 |
| $\mathbf{Q_3}$: 9.4920 | $Q_3$ :350.510 | $\mathbf{Q_3}$:31210.21 |
| **Max.** :34.7890 | **Max**. :351.358 | **Max**. :37913.36 |

***Table 1**: Descriptive statistics*

Table 2 shows the following result of correlation that may be exist between factors.

| | **Year** | **CO2 emission** | **Pop. Density** | **Adjusted net. Nation** |
|---|---|---|---|---|
| **Year** | 1.00 | | | |
| **$Co_2$ emission** | 0.00 | 1.00 | | |
| **Pop. Density** | 0.65 | 0.37 | 1.00 | 0.89 |

***Table2**: correlation factors*

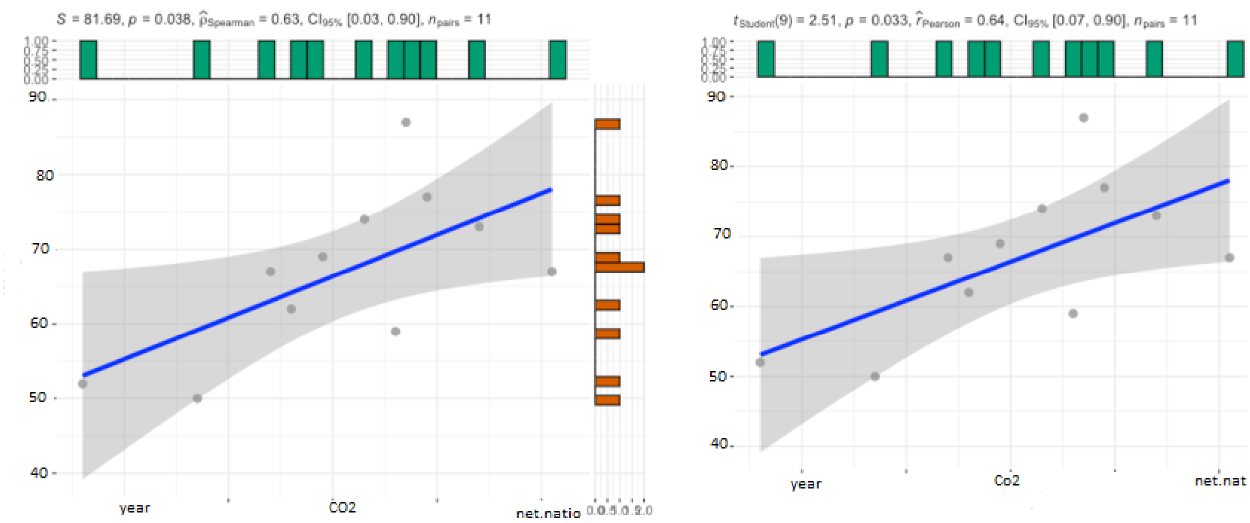


***Fig1***

A modest correlation was found in the end between CO2 emissions and two other parameters in the investigation. To sum up, the C0rrelation shows that there is a substantial positive correlation between CO2 emissions and the remaining 0ther components. A substantial correlation factor is found between carbon dioxide and the adjusted net national income source. Both sectors with high population density (R2 = 0.43) and those with high CO2 emissions per capita (R2 = 0.6) are examined in terms of their respective corrected R squares. Adjusted R square values for other sectors that fall within the range of 0.06–0.18 show that only a small fraction of the variance in CO2 emissions per capita, commercial, and freight transportation sectors can be attributed to changes in the BCI. We should also keep in mind that the industrial sector seems to be weak in our preferred cities. The lack of a discernible effect of urban form on commercial CO2 emissi0ns was surprising, but it may have reasonable explanations, such as the fact that commercial sectors are often concentrated in urban cores and that the size of commercial operations is typically small. Many population density form indexes omit these details.

## Hypothesis testing:

In statistics, hypothesis testing is the process of investigating the validity of a researcher's working assumption about some aspect of a sample's demographics. The analyst's approach will be shaped by the specifics of the data being analysed and the goals of the investigation. In order to determine whether or not a hypothesis can be supported by data, scientists employ hypothesis testing.

**Hypothesis(1)**

$H_{o:}$µ= population density has (no) effect on direct carbon emission per capita in japan.

$H_1$: µ=otherwise,

From the R results, the coefficient of our hypothesis testing are:

| Intercept | CO2 |
|---|---|
| 45.7213 | 0.000965 |

**Estimate Std. Error t value Pr(>|t|) Residual standard error: 3.127 ,Multiple R-squared: 0.7482, Adjusted R-squared:** 0.7309
**F-statistic:** 43.09 **on 2 and 29 DF, p-value:** 2.062e-09

From the given results, p-value=2.062e-09 and f statistic=43.09, we have a strong evidence to reject our null hypothesis.

**Hypothesis(2)**

$H_{o:}$µ= Househ0ld income per capita has (n0) effect on direct carb0n emissi0n per capita in japan.

$H_1$: µ=0therwise,

The coefficients of our hypothesis testing are:

| Intercept | CO2 |
|---|---|
| 34.569 | 0.00769 |

**Estimate Std. Err0r 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-value:** 1.078e-09

From the given results, p-value=1.078e-09 and f statistic=13.09, we have a strong evidence to reject our null hypothesis. Strongly agree that the household income per capita has (n0) effect on direct carbon emissions per capita in japan.

**Power-law function:**

A power-law relationship is one in which a proportional increase in one component leads to an increase in the other portion, regardless of the size of the aggregate to begin with.

Relationships between two values that may be represented as a = bx + k are called scalar, and they are explained by power laws.

Relati0nships On log-log graphs, the obeying power law appears as a straight line because the original equation is transformed into log(y) = klog(x) + log(a), which is the same form as the equation for a line. Standardizing the last three years of power-law data (2020, 2021, 2022).

| year | $CO_2$ emission | Pop. Density | Adjusted.net |
|---|---|---|---|
| **2020** | 9.302379 | 345.83 | 24800.64 |
| **2021** | 9.202486 | 347.41 | 27926.78 |
| **2022** | 0.323416 | 349.64 | 30029.82 |

***Table:1.3:*** *power-law function*


***Fig:2***

In figure 2, in 2020, 2021,2022 the power-law function indicates the possible turns in recent years. The graphical presentation shows that the linear relationship exist between the years. By log function, minimum value is 9.30 and the other factors are high.

**Diagnostic Tests**

The White test may be used by statisticians to ascertain whether or not the errors produced by a regression model are homoskedastic, meaning that their variance remains constant over time. An additional test for homoscedasticity in regression analysis is to regress the squared residuals from the main model on the set of original regressors, the cross-products of the regressor, and the squared regressor.

**Hypothesis:-**

White's test, null and alternative hypotheses mentioned as follows

Null (H0): Homoscedasticity is present.

Alternative (H1): Homoscedasticity is not present.

By the regression model summary, if the heteroskedasticity is present, then find the studentized Breusch-Pagan test.

| studentized Breusch-Pagan test | Df | p-value |
|---|---|---|
| 13.75 | 19 | 0.1317 |

**Inference:-**

The test statistic is 13.745, the degree of freedom is 9 and the corresponding p-value is **0.1317**.We cannot reject the null hypothesis because the p-value is greater than 0.05. We do not have enough.

## DISCUSSION

For the omission of CO2 multicollinearity, just describe the exact multicollinearity in the explanatory variable. Our null hypothesis is supported by strong evidence, as shown by a variety of graphical representations. Even more so, imports from Japan do not add to the region's pollution levels per capita, whereas imports from Japan do. The findings demonstrate that: there is a significant difference in household emissi0ns across age groups; older households tend to pr0duce higher levels of emissi0ns per capita; decreasing temperatures are the primary cause of the increased emissi0ns in older households, whereas they play a much smaller role in younger households; Summarized are the results, which show that the high levels of emissions produced per person in older households are a result of inefficient energy consumption among the elderly. One of the fastest growing sectors in terms of carbon dioxide emissions is the transportation sector. The transportation sector as a whole had an annual growth of 9% in CO2 emissions between 1990 and 2008, but CO2 emissions from roads grew at a faster clip (2.6% per year). The findings reveal connections between geographical indicators of urban form and emissions of carbon dioxide from automobiles and homes.

## CONCLUSION

Despite substantial disparities in industrial structure and transformation, population, and local weather conditions by standardised three years, this holds true for all of these places. Local governments have been effective in reducing CO2 emissions per resident, despite popular belief to the contrary. We utilised information from the World Development Indicators, taking into account variations in GDP, population density, and greenhouse gas emissions throughout many years. Strong evidence against the null hypothesis based on our data. As shown by several statistical methods (multicollinearity, power-law function, regression line model), per capita direct carbon emissions in Japan are unrelated to either family income or population density. Provide visual evidence of the presence of heteroskedasticity in the data collection.

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