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Car ownership and household activity emissions in Japan – from the time-use perspective

Yida Jiang[1*], Tomohiko Ihara [2]

1 Graduate Program in Sustainability Science - Global Leadership Initiative, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan

2 Department of Environment Systems, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan

ABSTRACT

Car ownership significantly impacts the patterns in household consumption and time use. In this study, combining microdata from national expenditure survey and time use survey, carbon emissions of 85 daily household activities covering 24 hours in the day are estimated from a novel time-use perspective for Japanese households with and without private car ownership, respectively. Results indicate that while households with cars on average have higher emissions from transportation-related activities, their daily emissions from non-transportation activities are lower than households without cars. Policies targeting consumption behavior should therefore be devised based on the different activity emission patterns of different households.

Keywords: carbon emission, car ownership, household activity, time-use, carbon mitigation, behavioral change

1. INTRODUCTION

In the past decades anthropogenic greenhouse gas (GHG) emissions have been rising, largely due to the growth in energy demand by material consumption. The consequential environmental issues caused by growth in anthropogenic GHG emissions have aroused worldwide concerns and have prompted researchers to explore mitigation strategies targeting households' consumption behavior.

A fundamental step to the exploration of mitigation potential in household behavioral change is estimating the energy use and associated GHG emissions induced by households' consumption behavior. The estimation can be performed by using environmentally-extended input-output (EEIO) tables and data of household expenditures [1], which is adopted by most existing studies. However, apart from expenditures, time is also a constituent of the consumption behavior. As for everyone there are only 24 hours in a day, the ways in which household members allocate time to various daily activities determine their consumption patterns. A time-use perspective combining expenditure and time use patterns is capable of producing a comprehensive account of the GHG emissions from daily activities.

It has also been indicated that the socioeconomic and demographic characteristics of households, e.g. population density, household size, income, education, car ownership etc. [2] influence household expenditure patterns, and consequently their carbon footprints. Since time-use perspective has been rarely adopted by existing studies, impacts of variations in time use patterns on household activity emissions due to varying socioeconomic characteristics of households have never been studied. In this paper, we focus on the impacts of car ownership on the GHG emissions from household activities in Japan. By linking data on household expenditures and time use, we estimate the GHG emissions of 85 daily activities covering 24 hours of the day for households with various socioeconomic and demographic characteristics. The results have implications for potential carbon mitigation strategies targeting daily activity patterns of households with and without privately owned cars.

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2. METHODOLOGY

2.1 Principal datasets

This study principally utilizes three principal datasets: household expenditure data, time use data, and GHG intensity of expenditure data. Household expenditures are provided by the anonymized microdata (containing responses from single households) of 2004 National Survey of Family Income and Expenditure (NSFIE) [3], which surveyed household expenditures on 320 consumption items on a sample of 48,007 households distributing over all 47 prefectures of Japan. Time use is provided by the anonymized microdata of the Questionnaire B of 2006 Survey of Time Use and Leisure Activities (STULA) [4], which has a sample size of 18,291 time use records reporting on respondents' starting and ending time of 85 daily activities (84 activities, except for "Other", have registered time use) at 15-minute intervals. Both datasets are the latest versions of respective surveys for which microdata is available.

The GHG intensity of expenditure is the GHG emissions occur for per unit expenditure. Indirect GHG intensity of expenditure is derived based on the data provided by the 2005 Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID) [5] derived using EEIO tables and the global extension developed by Nansai et al. for 2005 3EID [6]. Direct emissions include CO_2 resulting from the combustion of fossil fuels, e.g. city gas, kerosene, liquid propane, gasoline, and other GHGs such as CH_4, N_2O, and fluorinated gases (HFCs, PFCs, SF_6), which are all converted into CO_2-equivalent (CO_2e) according to the global warming potential of each gas. Direct GHG intensity of expenditure is obtained by dividing the total GHG emissions in 2005 3EID [5] by the total household expenditures on items leading to direct emissions in an expanded list of household expenditures in combing 2004 NSFIE and 2004 Family Income and Expenditure Survey (FIES) [7].

2.2 Matching household expenditures and time use

Daily activities are regarded as a combination of the expenditures on the consumption items and time required for conducting the activities. It is therefore necessary to allocate the expenditures on consumption items to the time spent on each activity. Consumption items (a total of 320) covered by NSFIE are matched with at least one of the 85 activities covered by STULA. Since different activities use consumption items by different quantities, expenditures on each consumption item are decomposed into different shares each corresponding to an activity. The shares of the allocation are determined based on the relative time lengths of activities that use the corresponding consumption item, wherever relevant data illustrating the allocation of expenditures to activities is unavailable. This arrangement is reasonable in that empirically, the time length of an activity is positively related to the quantity of consumption required for it. The shares a_{ij} in this allocation scheme can be express by the following equation:

$$a_{ij} = \frac{t_j}{\sum_j t_{ij}} \tag{1}$$

where t_j is the total length of time spent on activity j. t_{ij} is the time length of activity j that involves the consumption of consumption item i.

Data from surveys on transportation and energy use is utilized in determining the shares of transportation and energy expenditures for activities. Data on transportation is provided by National Survey on Urban Transportation Characteristics (NSUTC) [8]. Total travel time for each means of transportation for each purpose is derived by multiplying the average number of trips per day (2005 NSUTC) with the average time per trip (2015 NSUTC). Shares of transportation-related expenditures are then determined by the relative length of traveling time for each purpose corresponding to daily activities. For determining the shares of energy expenditures, the summary of 2009 Survey on Energy Consumption of the Household Sector [9], which reports on the shares of electricity and total energy use by various household appliances, is used. Relative average power consumption of each appliance is derived by dividing the shares of electricity/fuel use of the appliance by the total time of appliance use. Relative electricity/fuel use of an activity is then derived by multiplying the average power consumption of involved appliances with activity time length.

2.3 Matching households by car ownership

Households activity patterns are reflected in their expenditure and time use patterns. As NSFIE and STULA were conducted on two different samples and at different time, households contained in the microdata of the two surveys are matched by car ownership to produce synthesized household subgroups.

3. CALCULATING ACTIVITY EMISSIONS

The direct and indirect GHG emissions of a consumption item are expressed as:

$$E_i^{di} = e_i^{di} Exp_i \tag{2}$$

$$E_i^{in} = e_i^{in} Exp_i \tag{3}$$

where E_i^{di} and E_i^{in} represent correspondingly the direct emissions and indirect emissions of item i, e_i^{di} and e_i^{in} represent correspondingly the direct and indirect emission intensity of expenditure of item i, and Exp_i represent the household expenditure on item i. Combing equations (2) and (3), we can obtain the total emission E_j^{tot} of an activity j:

$$E_j^{tot} = \sum_i a_{ij} E_i^{tot} \quad (4)$$

4. RESULTS AND DISCUSSION

GHG emissions of transportation-related and non-transportation daily household activities are shown in Fig 1 and Fig 2, respectively. On average, households with cars emit 15.25 $kgCO_2e$/(cap・day), higher than households without cars, which emit 14.60 $kgCO_2e$/(cap・day). As Fig 1 suggests, the excess GHG emissions of households with cars are large contributed by transportation-related activities, which are 2.72 $kgCO_2e$/(cap・day) for households with cars and 0.92 $kgCO_2e$/(cap・day) for households without cars. A direct cause of this difference is the higher GHG intensity of per capita fuel use by private cars than alternative means of transportation for households without cars, such as public transportation, cycling, and walking, etc. It is also possible that households with cars tend to devote more time to traveling by traveling farther and more frequently due to the convenience offered by car ownership. Policies aiming at achieving emission mitigation may shorten car use time among owners by charging higher fuel taxes or tolls, or by encouraging the use of public transportation through subsidies to lower the cost or through infrastructural investments to improve the convenience of public transportation. Enhancing the convenience for cyclers and pedestrians in urban planning may also lead to more time being devoted to low-carbon transportation.

On the other hand, households without cars emit more regarding non-transportation activities (13.68 $kgCO_2e$/(cap・day)) than households with cars (12.54 $kgCO_2e$/(cap・day)), as Fig 2 suggests. Fig 2 also suggests that, for most daily activities households without cars emit more than households with cars. This is likely due to the higher purchasing power of households without cars, who are more likely to live in urban areas and thus more likely to have higher per capita income than households with cars. Policies are therefore likely to achieve larger mitigation in GHG emissions among households without cars by changing the time use patterns of carbon-intensive non-transportation activities, such as management of meals (cooking), medical examinations, etc.

5. CONCLUSIONS

The daily emissions of daily Japanese household activities are estimated for households with and without private cars, respectively. Results indicate that households with cars on average have higher total daily emissions, contributed by transportation-related activities, while their emissions from non-transportation activities are lower than households without cars. Policies aiming at carbon mitigation through behavioral change should therefore effect differently according to household car ownership.

REFERENCES

[1] Jiang Y, Long Y, Liu Q, Dowaki K, Ihara T. Carbon emission quantification and decarbonization policy exploration for the household sector - Evidence from 51 Japanese cities. Energy Policy 2020;140:111438.

[2] Minx J, Baiocchi G, Wiedmann T, Barrett J, Creutzig F, Feng K, et al. Carbon footprints of cities and other human settlements in the UK. Environ Res Lett 2013;8:035039.

[3] Statistics Bureau, Ministry of Internal Affairs and Communications. National Survey of Family Income and Expenditure. 2004.

[4] Statistics Bureau, Ministry of Internal Affairs and Communications,. Survey on Time Use and Leisure Activities. 2006.

[5] Nansai K, Moriguchi Y, Tohno S. Embodied energy and emission intensity data for Japan using input-output tables (3EID)–inventory data for LCA. Natl Inst Environ Stud Japan 2002;32.

[6] Nansai K, Kondo Y, Kagawa S, Suh S, Nakajima K, Inaba R, et al. Estimates of Embodied Global Energy and Air-Emission Intensities of Japanese Products for Building a Japanese Input–Output Life Cycle Assessment Database with a Global System Boundary. Environ Sci Technol 2012;46:9146–54. https://doi.org/10.1021/es2043257.

[7] Ministry of Internal Affairs and Communications. Family Income and Expenditure Survey 2004. https://www.stat.go.jp/english/data/kakei/index.html (accessed September 7, 2019).

[8] Ministry of Land, Infrastructure, Transport and Tourism. National Survey on Urban Transportation Characteristics 2015. http://www.mlit.go.jp/toshi/tosiko/toshi_tosiko_tk_000033.html (accessed November 11, 2018).

[9] Ministry of Economy, Trade and Industry . Summary of the 2009 Survey on Energy Consumption of the Household Sector (In Japanese). 2010.

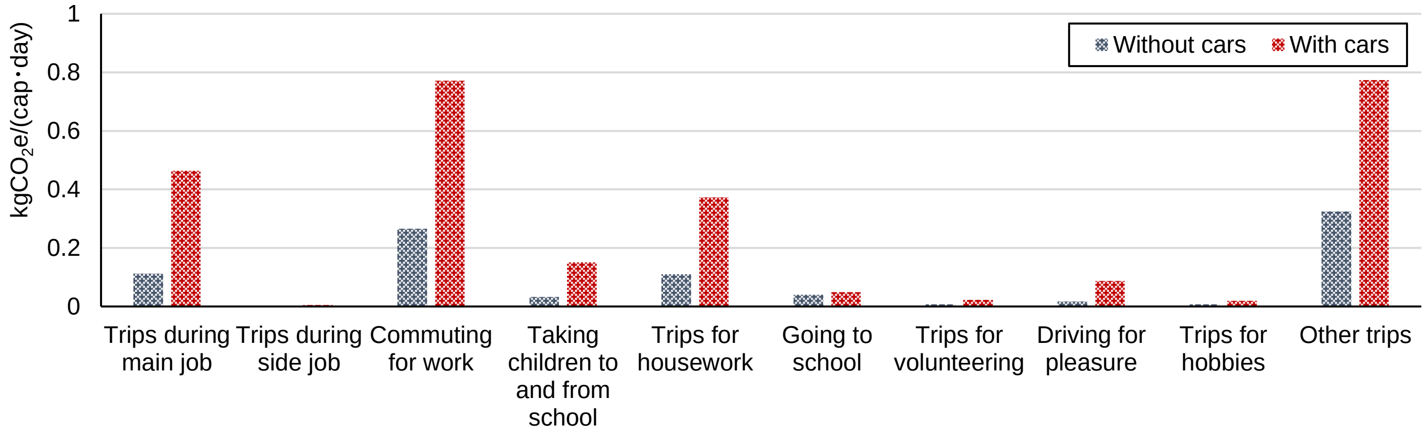

Fig 1 Daily GHG emissions of transportation-related household activities by car ownership.

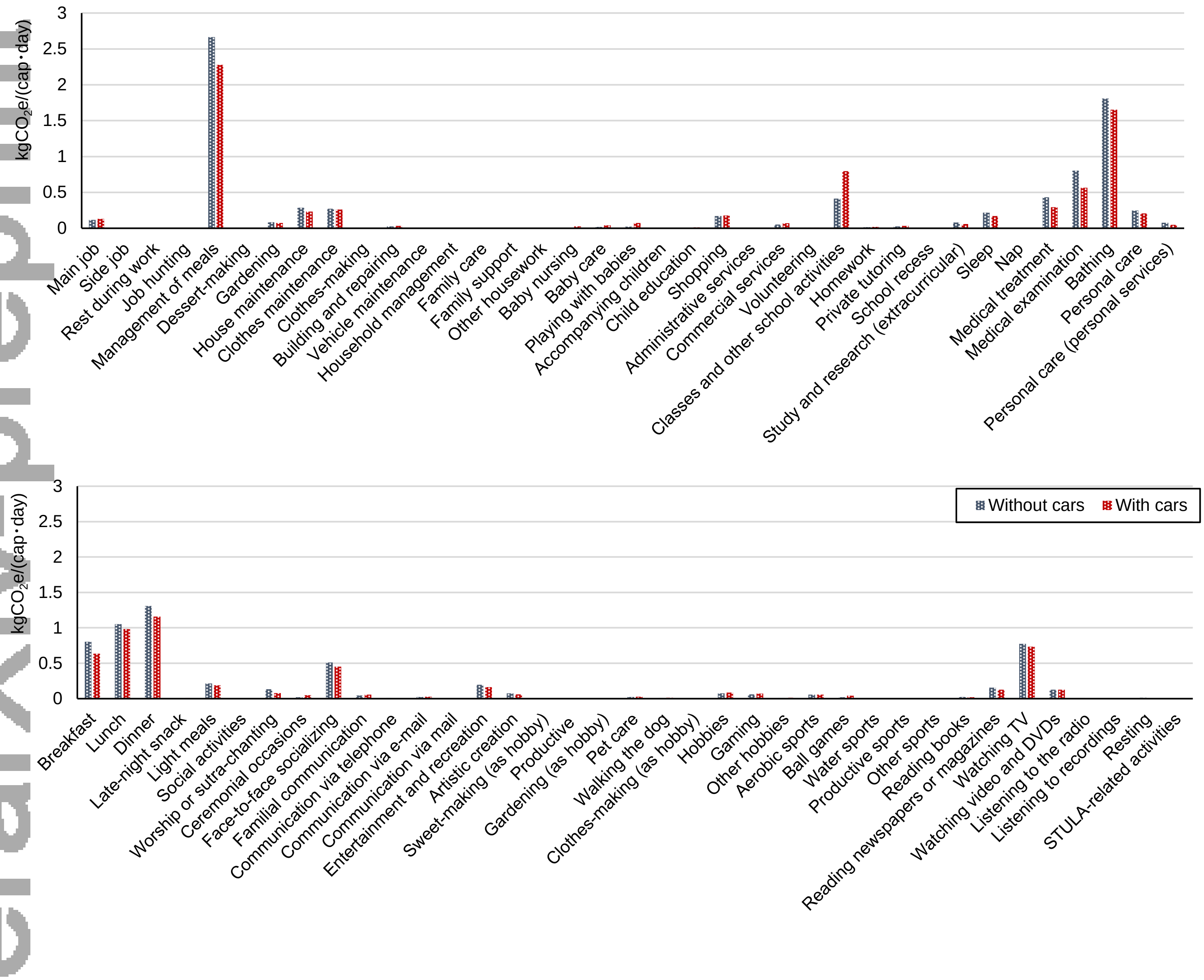

Fig 2 Daily GHG emissions of non-transportation household activities by car ownership.