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Impacts of Declining and Aging Population on Urban CO_2 Emissions: The Case of Japanese Cities

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人口減少・高齢化がもたらす都市部二酸化炭素排出量への影響：日本の都市を事例に
（要旨）

国立社会保障・人口問題研究所によると，日本の人口は，2010 年そのピークに達した後徐々に減少し，2060 年には 9 千万人を下回ると予測されている。これは 1955 年の人口とほぼ同じである。2010 年～2015 年の間の平均人口増加率は-0.08%となり，これは人口百万人以上の 158 ヶ国の中で 142 番目の増加率である。出生率の低下に伴い，日本の 0～14 歳の年少人口（そのピークは 1955 年）および 15～64 歳の生産人口（そのピークは 1995 年）が徐々に減少していく一方，65 歳以上の高齢人口（そのピークは 2040 年）は増加していくことが予測されている。よって，特に対策がとられない現状が続けば，今後，日本の人口は減少し，そしてさらに高齢化していくこととなる。今までに経験したことのない人口減少・高齢化にどのように対応していくべきか？ それに対する答えを検討するためには，まず人口減少・高齢化がどのような影響をもたらすのかを事前に検証していくことが不可欠である。しかしながら，人口減少・高齢化が経済面あるいは社会面へ及ぼす影響についての議論は高まってきている一方，それが環境面へどのような影響を及ぼすかについての議論はあまり高まっていない。一方，我が国の自治体に目を向けると，北九州市など政府から環境モデル都市あるいは環境未来都市に選定されている自治体を含め多くの自治体が経済・社会・環境面においてバランスのとれた発展をまちづくりのビジョンとしている。特に，自然エネルギーの普及や温室効果ガスの削減などは自治体が重要な役割を担っている吃緊の課題である。環境面での取り組みにおいて世界から高く評価されている北九州市は，20 ある政令都市の中で一番早く人口減少・高齢化に直面し，2010 年時点の高齢者人口割合（25.2%）は政令都市の中で一番高いこともあり，北九州市の人口減少・高齢化への取り組みは，我が国の他自治体のみならず，今後徐々に人口減少・高齢化を迎えるアジアの国々など世界からも注目されていくはずである。環境のみならず人口減少・高齢化にも配慮したまちづくりとはどうあるべきか，世界の環境首都を目指す北九州市にとって大きな課題である。

本研究は，この大きな課題に貢献することを背景に 2013 年度 ICSEAD 研究プロジェクトとして実施した。本研究の目的は，人口減少・高齢化が，都市の家庭部門と交通（旅客）部門におけるエネルギー（化石燃料）消費の結果として発生する二酸化炭素（以下，CO_2）排出量にどのような影響をもたらすかを日本の都市データを使って明らかにすることである。都市の家庭部門と交通（旅客）部門におけるエネルギー消費によって発生する CO_2 排

出量の増減率は, 1 人当たりの CO_2 排出量の増減率と都市人口の増減率によって決定することから，本研究では，まず，日本の 712 都市の横断的データを使って，家庭部門と交通（旅客）部門における都市の CO_2 排出量と都市の人口との関係を分析した。分析結果からは, 1990 年および 2000 年の両データにおいて, 都市の CO_2 排出量と都市の人口規模との間に強に正の関係をみることができた。次に，高齢者人口の多寡が家庭部門と交通（旅客）部門における都市の 1 人当たり CO_2 排出量に与える影響の有無を明らかにするため，上述の日本の都市データ（2000 年）を使って，都市の 1 人当たり CO_2 排出量を被説明変数とし，気温，人口密度，1 人当たり所得，そして高齢者人口割合を説明変数とする重回帰分析を家庭部門と交通（旅客）部門のそれぞれについて行った。分析結果からは，高齢者人口割合の都市の 1 人当たり CO_2 排出量への影響は, 家庭部門については 5%の有意水準で統計学的に有意である一方，交通（旅客）部門については 5%の有意水準では統計学的に有意でないという結果となった。すなわち，家庭部門については，高齢者人口割合が大きい都市ほど家庭部門における 1 人当たり CO_2 排出量が大きいということを示唆する。これは，高齢者人口割合が大きくなると高齢者世帯（単身および夫婦）数とその割合が大きくなり，そして，それが一般世帯数を増加させる結果，人口増加率が小さい（あるいはマイナス）の下では 1 世帯当たり平均人員数（人口/世帯数）が小さくなるためである。本研究結果から，人口減少・高齢化によって都市のエネルギー（化石燃料）消費の結果として発生する CO_2 排出量が増えるか減るかは，家庭部門においては，人口減少の大きさと都市の 1 人当たり CO_2 排出量の決定要因の 1 つである高齢者人口割合の大きさに依存することがわかった。

本研究の重回帰分析にてデータとして使用した都市の CO_2 排出量は直近である 2000 年のものを使用したが，2013 年 12 月に環境自治体会議より 1990 , 2000, 2007, 2008, 2009 そして 2010 年の市町村別および部門別の CO_2 排出量統計が発表された。2014 年度も継続して実施する本研究では，これら最新の時系列データを使って同様の分析を試みると共に，特に交通（旅客）部門の重回帰モデルをより精緻にしたいと考えている。さらには，北九州市を含む 20 の政令都市に対象を絞り，人口減少・高齢化が都市のエネルギー消費（都市の CO_2 排出量）にもたらす影響のメカニズムについてさらに掘り下げた分析を行いたいと考えている。本研究が，環境のみならず人口減少・高齢化にも配慮したまちづくりに向けた北九州市の取り組みを検討するに当たって，僅かのヒントでも提供することが出来れば幸いである。

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CONTENTS

1. Introduction

After having reached its peak in 2010, Japanese population is predicted to be gradually declining and aging. Declining and aging population is what Japan has never experienced in the past. How to respond to this unprecedented issue? To answer this question we have to examine a wide range of expected impacts of declining and aging population. While its impacts on economy and society attract attention, its impacts on the environment do not. This study focuses on the impacts of declining and aging population on the environment, particularly the carbon dioxide (hereafter CO_2) emissions in urban areas which have dense population. Since many Japanese cities are anxious to become ECO-CITIES with ambitious targets in CO_2 emissions reduction to contribute to climate change mitigation[1], it is worth investigating what would happen to their CO_2 emissions when their population are declining and aging.

The purpose of this study is to investigate the impacts of declining and aging population on urban CO_2 emissions, particularly in residential and transport (passenger) sectors. Since time-series data on CO_2 emissions of Japanese cities, which are probably more appropriate to investigate the impacts of declining and aging population on urban CO_2 emissions, are not available, this study uses cross-sectional data on CO_2 emissions of Japanese cities instead.

The next section sees the transitions in Japan's population with its age composition and also in the number of Japan's households with different age groups. Section 3 investigates the relationship between urban population and urban CO_2 emissions in residential and transport (passenger) sectors using the cross-sectional data of Japanese cities for 1990 and 2000. Section 4 conducts a multiple regression analysis to investigate whether there is an impact of aging urban population on urban per capita

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[1] ECO-CITY is a word which combines ecology with city. Though it can be simply defined as an environmentally friendly city, its concept has actually broad implications. For example, the concept of Environment Future City in Japan which is one type of ECO-CITY includes economic and social aspects (for example, revitalization of local economies, livable for every citizen) as well as an environmental aspect. There are 11 cities and regions including Kitakyushu-City designated as Environment Future City by Japanese government.

CO_2 emissions in residential and transport (passenger) sectors using the cross-sectional data of Japanese cities for 2000, which is the latest data on urban CO_2 emissions available. A multiple regression analysis shows that the impact of aging urban population on urban per capita CO_2 emissions in a residential sector is statistically significant. Then, Section 5 analyzes why aging urban population has the impact on urban per capita CO_2 emissions in a residential sector. Finally, Section 6 concludes summarizing the study findings and briefly discussing their implications.

2. Transitions in Population and the Number of Households

After having reached its peak in 2010, the population in Japan (including foreigners) started to decline and is predicted to continue to decline (Figure 1). In 2010, the population in Japan (including 1,648,037 foreigners) is 128,057,352 (e-Stat)[2]. Its average growth rate during 2010-2015 is -0.08% which ranks 142th among 158 countries with the population of more than one million (UN).

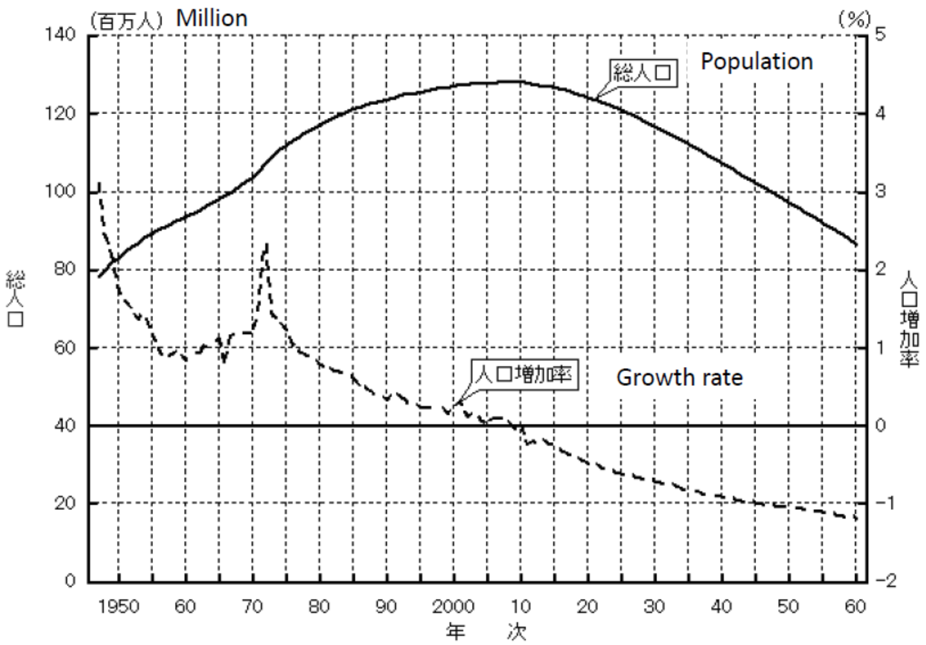

Figure 1. Transition in Japan's Population with Its Growth Rate (1947-2060)
Source: National Institute of Population and Social Security Research: Population Statistics 2014, Figure 1-2. Note: Population includes foreigners.

[2] Japanese population (not including foreigners) reached its peak in 2007 (126,347,000) (e-stat).

Japan's juvenile population aged under 15 and working population aged 15-64 started to decline around 1980 and 1995 respectively while its elderly population aged 65 and more is continuously increasing even after its total population started to decline (Figure 2). As of 2012, the ratio of elderly population in the working population of 100 is 38.4 while the ratio of elderly population in the juvenile population of 100 is 186.1 which is the highest among major countries followed by Germany (155.8) and Italy (144.2) (National Institute of Population and Social Security Research: Population Statistics 2014).

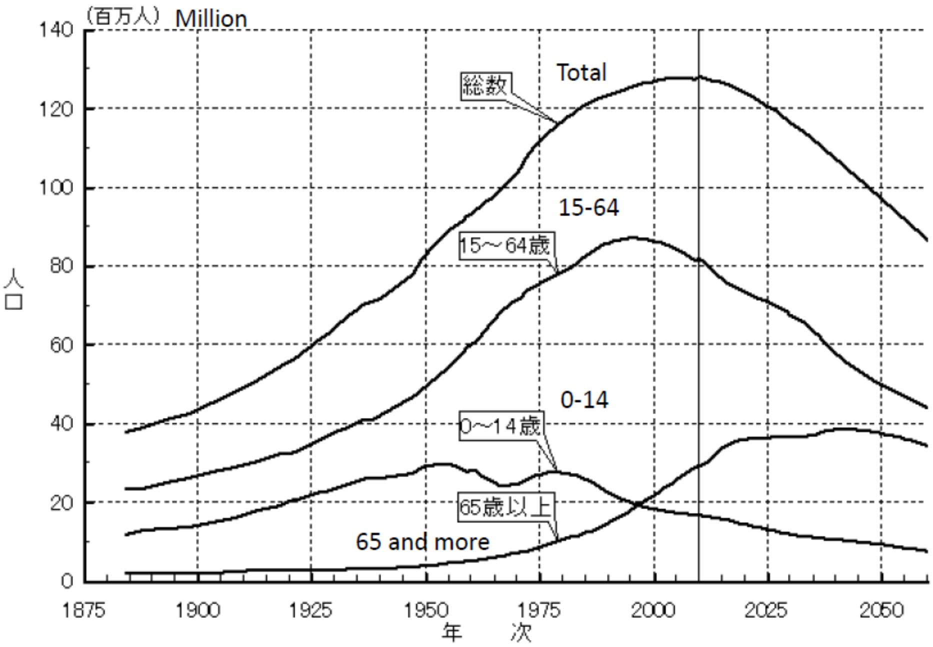

Figure 2. Transition in the Age Composition of Japan's Population (1884-2060)
Source: National Institute of Population and Social Security Research: Population Statistics 2014, Figure 2-2.

While Japan's population is continuously declining and aging, the number of its households is predicted to continuously increase and reach its peak in 2020 (53,053 thousand households) (Figure 3). Furthermore, the shares of elderly households (couple and single) are continuously increasing during 1980-2035. The share of elderly couple households which was only 3.5% in 1980 is expected to reach 12.6% in 2035. The share of elderly single households which was only 2.5% in 1980 is expected to reach 15.4% in 2035. Accordingly, the total share of elderly households (couple and single) which was only 6.0% in 1980 is expected to reach 28.0% in 2035. Along with an increase in the share of elderly households during 1980-2035, the average number of household members is decreasing during the same period (Figure 4). Actually the share of elderly households is negatively highly correlated to the average number of household members. According to the data on the share of elderly households and the average number of household members during 1980-2035, a correlation coefficient between them is -0.988. Therefore, it could be assumed that an increase in the share of elderly households is likely to decrease the average number of household members. (This point is discussed in more detail in Section 5.) The number of household members is an important factor in terms of its impact on energy consumption in residential and transport (passenger) sectors and thus on CO_2 emissions because it determines an efficient use of electricity, heating and gasoline by a household. For example, per capita energy consumption at a household with a smaller number of household members is likely to be bigger than per capita energy consumption at a household with a larger number of household members.

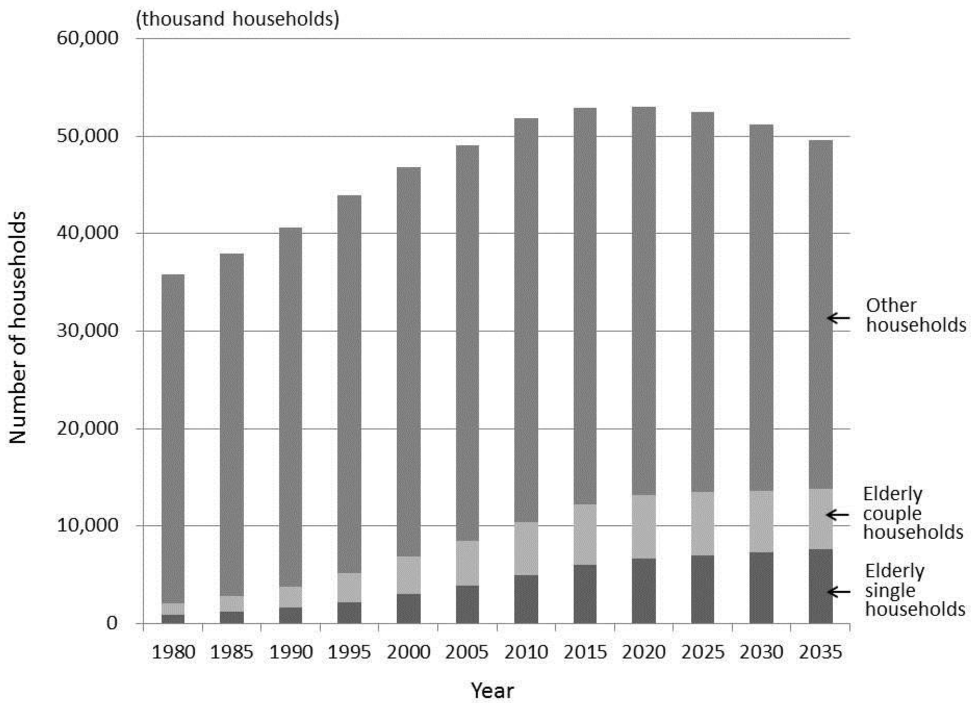

Figure 3. Transition in the Number of Japan's Households (1980-2035)
Source: National Institute of Population and Social Security Research, 2013.

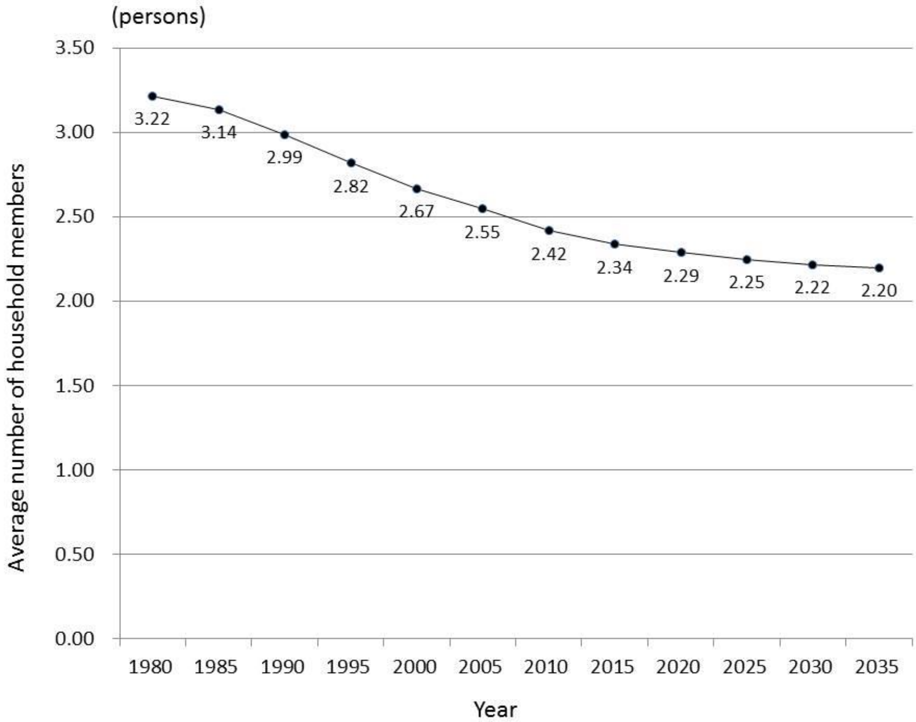

Figure 4. Transition in the Average Number of Japan's Household Members (1980-2035)

Source: National Institute of Population and Social Security Research, 2013.

In sum, the projection on the transitions in Japan's population and the number of Japan's households suggests the following relationship:

Declining and aging population
⇩
An increase in the share of elderly households
⇩
A decrease in the average number of household members.

3. Relationship between Urban Population and Urban CO_2 Emissions

As of 2011, the population of 788 cities in Japan (including Tokyo's 23 special wards counted as one city) is 114,947,770, which accounts for 91.9% of Japanese population of 126,180,000 (Table 1). As Table 1 shows, small cities account for a half of Japanese urban population. It suggests that small cities as well as medium and large cities must play an important role in reducing Japanese urban CO_2 emissions.

Table 1. Japanese Cities by Population Scale (2011)

Population scale	Number	Total population(1)	
		Persons	Share (%)
Small cities (less than 300,000)	715	58,571,069	51.0
Medium cities (300,000-less than 500,000)	45	17,358,245	15.1
Large cities (more than 500,000)	28	39,018,456	33.9
Government-designated cities(2)	20	26,549,773	23.1
Tokyo's 23special wards	1	8,591,695	7.5
Others	7	3,876,988	3.3
Total	788	114,947,770	100.0

Data source: MIAC, e-Stat.
(1): Population is Japanese population.
(2): As of 2012, there are 20 government-designated cities. They are Sapporo, Sendai, Chiba, Saitama, Kawasaki, Yokohama, Sagamihara, Shizuoka, Hamamatsu, Niigata, Nagoya, Kyoto, Osaka, Sakai, Kobe, Okayama, Hiroshima, Kitakyushu, Fukuoka and Kumamoto.

Since an interest in this study is the impact of a change in population and households on CO_2 emissions, the study focuses on CO_2 emissions in residential and transport (passengers) sectors which are directly affected by a change of population and households[3]. CO_2 emissions in residential and transport sectors share 15.2% and 18.5% of total Japanese CO_2 emissions respectively in 2011 (Table 2). Furthermore, CO_2 emissions in these two sectors increased by 48.8% and 6.0% respectively in 2011 from the 1990 level while CO_2 emissions in a sector of business and others which shares 20.0% also increased by 34.8%. As mentioned above, urban population shares 91.9% of Japanese population. Therefore, urban areas must play an important role in reducing Japanese CO_2 emissions in residential and transport (passengers) sectors.

[3] Though energy consumption and thus CO_2 emissions in a sector of business and others is indirectly affected by a change of population and households (for example, the number/scale of commercial facilities is affected by the number of consumers), the mechanism which determines CO_2 emissions in this sector is more complicated.

Table 2. Japanese CO_2 Emissions by Sector (2011)

Sectors	Emissions[(1)] (million tons-CO_2)	Share in total emissions (%)	Change from 1990 (%)
Industry (factories and etc.)	419.0	33.8	-13.1
Business and Others (commerce, services, offices and etc.)	248.0	20.0	34.8
Residential	189.0	15.2	48.8
Transport (passengers and freight)	230.0	18.5	6.0
Energy conversion (power plants and etc.)	87.4	7.0	-0.5
Others (industrial process, waste incineration and etc.)	67.5	5.5	-17.7
Total	1,240.9	100.0	8.7

Data source: NIES.
(1): Emissions are indirect emissions which are based on indirect consumption of fossil fuel energy. Emissions from the consumption of the electricity generated by power companies and the heat generated by heat supply operators are allocated to each sector.

Figures 5 and 6 show linear correlations between population and CO_2 emissions in a residential sector of 712 Japanese cities for 1990 and 2000 respectively. A higher coefficient of a regression line for 2000 (1.213) compared to the one for 1990 (1.089) reflects an increase of CO_2 emissions in a residential sector during 1990-2000. Total CO_2 emissions in a residential sector of 712 cities are 99.8 million tons for 1990 and 126.0 million tons for 2000. The correlation coefficients, 0.979 for 1990 and 0.984 for 2000, show a very strong positive relationship between urban population and CO_2 emissions in a residential sector. Figures 7 and 8 show linear correlations in a transport (passenger) sector for 1990 and 2000 respectively. A higher coefficient of a regression line for 2000 (0.737) compared to the one for 1990 (0.564) reflects an increase of CO_2 emissions in a transport (passenger) sector during 1990-2000. Total CO_2 emissions in a transport (passenger) sector of 712 cities are 64.4 million tons for 1990 and 93.1 million tons for 2000. The correlation coefficients, 0.950 for 1990 and 0.941 for 2000, show a very strong positive relationship between urban population and CO_2 emissions in a transport (passenger) sector as well.

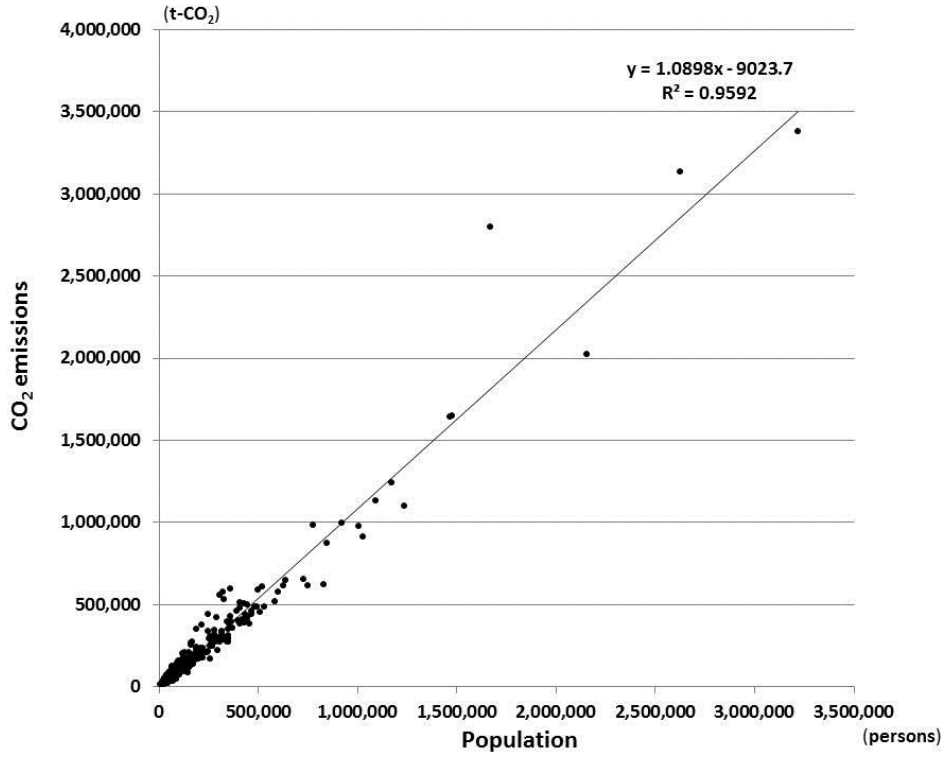

Figure 5. Population and Residential CO_2 Emissions of 712 Cities (1990)
Data source: Population (e-Stat); Residential CO_2 emissions (COLGEI 2007).

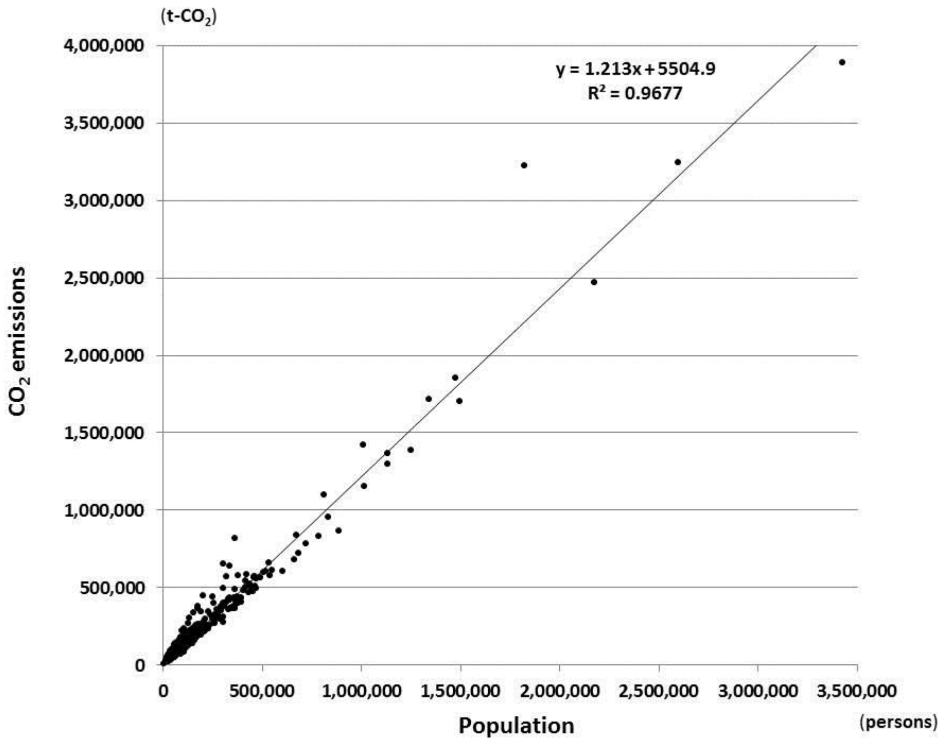

Figure 6. Population and Residential CO_2 Emissions of 712 Cities (2000)
Data source: Population (e-Stat); Residential CO_2 emissions (COLGEI 2007).

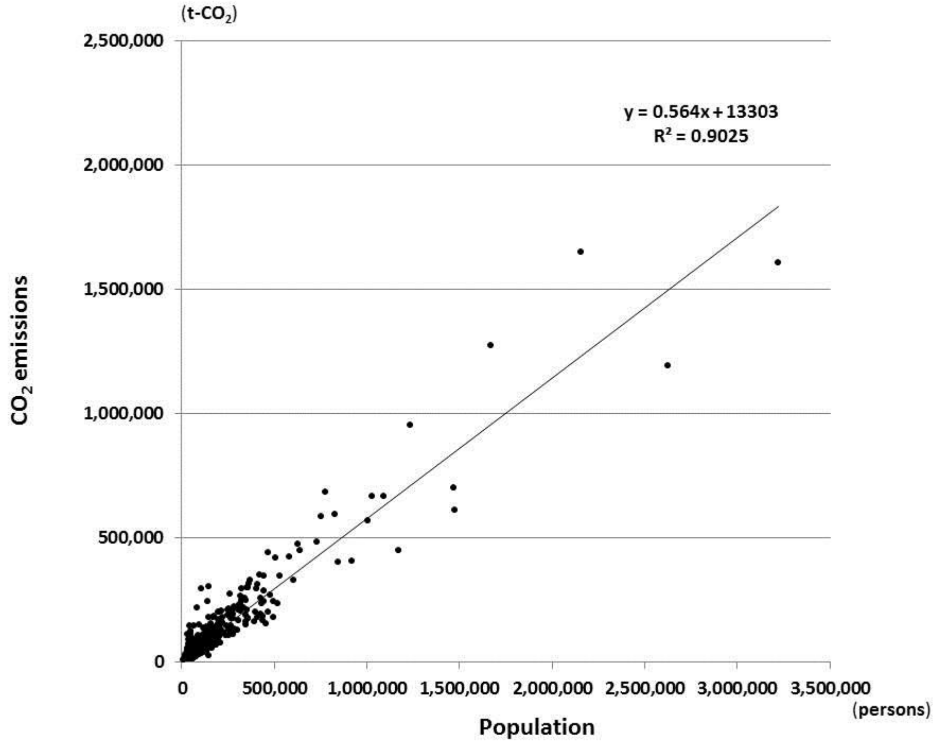

Figure 7. Population and Passenger Transport CO_2 Emissions of 712 Cities (1990)
Data source: Population (e-Stat); Residential CO_2 emissions (COLGEI 2007).

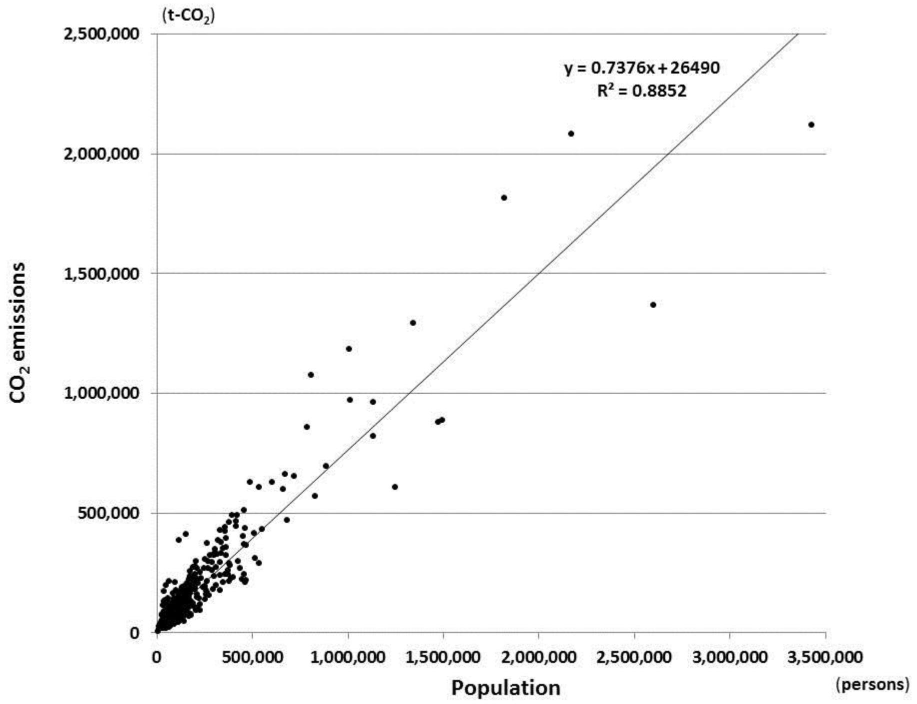

Figure 8. Population and Passenger Transport CO_2 Emissions of 712 cities (2000)
Data source: Population (e-Stat); Residential CO_2 emissions (COLGEI 2007).

4. Impacts of Aging Population on Urban Per Capita CO_2 Emissions: Multiple Regression Analysis

4-1. Theoretical Framework

There are two ways to estimate CO_2 emissions in various sectors. One way is based on direct consumption of fossil fuel energy such as coal, oil and natural gas. Another way is based on indirect consumption of fossil fuel energy. The multiple regression analysis in this study uses the data on CO_2 emissions in residential and transport (passenger) sectors. CO_2 emissions in a residential sector are estimated based on indirect consumption of fossil fuel energy. In other words, CO_2 emissions in a residential sector are allocated according to the consumption of electricity generated using fossil fuel energy by power companies and heat generated using fossil fuel energy by heat supply operators[4]. CO_2 emissions in a transport (passenger) sector are based on direct consumption of gasoline. The consumption of fossil fuel energy in these two sectors is basically decomposed into two parts, per capita consumption of fossil fuel energy and population[5]. (It can be alternatively decomposed into per household consumption of fossil fuel energy and a total number of households.) Therefore, urban consumption of fossil fuel energy in residential and transport (passenger) sectors, or in a sector *j* in general, can be expressed by an identity (1).

$$[\text{Urban consumption of energy}_k \text{ in a sector } j\,] = \sum_{k=1}^{3} [\text{Urban per capita consumption of energy}_k \text{ in a sector } j\,] \times [\text{Urban population}] \qquad (1)$$

where k = 1 (coal), 2 (oil), 3 (natural gas)

j = 1 (residential sector), 2 (passenger transport sector)

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[4] In the measurement based on direct consumption of fossil fuel energy, CO_2 emissions in a residential sector becomes much smaller whereas those in an energy conversion sector which generates electricity and heat becomes much larger.

[5] For an industry sector the consumption of fossil fuel energy can be decomposed into energy consumption per unit of production and total production. For a sector of business & others it can be decomposed into electricity and heat consumption per unit of office space (km^2) and total office space. For a sector of energy conversion sector it can be decomposed into energy consumption per unit of power (or heat) and total power (heat) generated.

Then, urban CO_2 emissions in these two sectors can be expressed by an identity (2).

$$[\text{Urban } CO_2 \text{ emissions in a sector } j\,] = \sum_{k=1}^{3} [\text{Urban per capita consumption of energy}_k \text{ in a sector } j\,] \times [CO_2 \text{ emissions coefficient of fossil fuel energy } k] \times [\text{Urban population}] \quad (2)$$

where k = 1 (coal), 2 (oil), 3 (natural gas)

j = 1 (residential sector), 2 (passenger transport sector)

Finally, an identity (2) can be rewritten in the following simpler identity (3).

$$[\text{Urban } CO_2 \text{ emissions in a sector } j\,] = [\text{Urban per capita } CO_2 \text{ emissions in a sector } j\,] \times [\text{Urban population}] \quad (3)$$

Where j = 1 (residential sector), 2 (passenger transport sector)

4-2. Multiple Regression Model

An identity (3) indicates that urban per capita CO_2 emissions in a sector j and urban population determine urban CO_2 emissions in a sector j. As shown in Section 3, there is a strong relationship between urban CO_2 emissions and urban population in residential and transport (passenger) sectors. This section investigates whether there is an impact of aging population on urban per capita CO_2 emissions in residential and transport (passenger) sectors by conducting a multiple regression analysis on the data of Japanese cities.

An identity (3) can be rewritten simply by taking logarithms of both sides to derive an equation (4). An equation (4) indicates that the percentage change in urban CO_2 emissions in a sector j is a result of the percentage change in per capita CO_2 emissions in a sector j and the percentage change in urban population.

$$\ln urban\ CO_2\ emissions_j = \ln per\ capita\ CO_2\ emissions_j + \ln urban\ population_j \quad (4)$$

where j = 1 (residential sector), 2 (passenger transport sector)

A multiple regression model to investigate an impact of aging population on urban per capita CO_2 emissions in residential and transport (passenger) sectors is shown in an equation (5). As explanatory variables, temperature (C°), population density (persons/ha) and per capita income (thousand yen) in addition to the share of elderly population aged 65 and more (%) are selected.

$$\textit{Per capita } CO_2 \textit{ emissions}_{ij} = \beta_0 + \beta_1 * temperature_i + \beta_2 * \textit{share of elderly pop}_i + \beta_3 * pop.density_i + \beta_4 * \textit{per capita income}_i + \varepsilon_{ij} \quad (5)$$

where i = 1, 2, -----n (cities)

j = 1 (residential sector), 2 (passenger transport sector)

4-3. Data

To investigate an impact of aging population on urban per capita CO_2 emissions, a multiple regression analysis was made on the latest available data of CO_2 emissions of Japanese cities in 2000. In Japan, there were 671 cities as of 1999. However, after the municipal mergers that started in 1999 and lasted until 2010, there are now 787 cities[6]. For this study, however, the data of 709 cities are used because of the following reason. One list of Japanese cities, for which the data on their CO_2 emissions in 2000 are available, is as of 2005. On the other hand, another list of Japanese cities, for which the other data such as the share of elderly population, population density, and per capita income in 2000 are available, is as of 2000. Therefore, some cities are not found in the both lists while all of necessary data for a regression is not available for a few cities. As a result, the number of cities for which all of necessary data are available is 709 cities. In addition, these 709 cities do not include Tokyo's 23 special wards because their population is too big (8,134,688 in 2000) compared with other cities (the population of Yokohama, the second largest city after Tokyo's 23 wards, is 3,426,651) though they are generally counted as one city.

[6] As of 1999, there were 3,229 municipalities (671 cities, 2,558 towns and villages) in Japan. However, the number of municipalities is now almost the half after the municipal mergers. As of March 31, 2010, there are 1,728 municipalities (787 cities, 941 towns and villages).

The data on CO_2 emissions of Japanese cities are available from the Coalition of Local Governments for Environment Initiative for the years of 1990 and 2000 (COLGEI 2007)[7]. Other data on explanatory variables such as the share of elderly population (with the age of 65 and more), population density, and per capita income of Japanese cities are available from e-Stat (Portal site of official statistics of Japan by Japanese Ministry of Internal Affairs and Communications). COLGEI estimates CO_2 emissions in a residential sector for the years of 1990 and 2000 based on: 1) per capita fuel consumption (including electricity, city gas, LPG and kerosene) by number of household members collected from the household survey which is conducted by the Ministry of Internal Affairs and Communications; 2) the number of households by number of household members; 3) the type of houses (detached house or condominium/apartment); and 4) CO_2 emissions coefficients by fuel (COLGEI 2007). COLGEI also estimates CO_2 emissions in a transport (passenger) sector for the years of 1990 and 1999[8] based on: 1) the number of automobiles (including passenger cars and buses) owned by municipality; 2) the amount of automobile running by municipality and type of automobile collected from road traffic census-automobile origin and destination survey (OD survey) which is conducted by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLITT); and 3) CO_2 emissions coefficients by type of automobile (COLGEI 2007). The share of elderly population in Japanese cities are available from e-Stat. Population density is calculated from the data on population and habitable land area, both of which are available from e-Stat. Per capita income is calculated from the data on total taxable income and population, both of which are available from e-Stat. Average annual temperatures of Japanese 47 prefectures are used

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[7] In collaboration with Japan's National Institute for Environmental Studies (NIES), COLGEI estimated CO_2 emissions by municipality (including cities, towns, villages and Tokyo's 23 special wards) and by sector (namely, manufacturing, business, residential, passenger transport, and freight transport) for the years of 1990 and 2000, 2007, 2008, 2009 and 2010 and published these data in December, 2013. At the time when this study was conducted the data on CO_2 emissions were available only for the years of 1990 and 2000.

[8] The data on CO_2 emissions in a transport (passenger) sector is not available for the year of 2000, but available for the year of 1999 when road traffic census-automobile origin and destination survey (OD survey) was conducted by MLITT.

for those of Japanese cities since the data on temperature for all of 709 Japanese cities are not available.

Table 3 shows the fundamental statistics of the data on these explained and explanatory variables in a multiple regression model (5).

Table 3. Fundamental Statistics of Explained and Explanatory Variables

(n=709 cities)

Variables	Mean	Standard deviation	Minimum value	Maximum value
[Explained variables]				
Per capita CO_2 emissions: Residential sector (t-CO_2)	1.309	0.290	0.796	2.439
Per capita CO_2 emissions: Transport (passenger) sector (t-CO_2)	1.050	0.415	0.337	4.747
[Explanatory variables]				
Temperature (^{o}C)	15.4	2.3	9.5	23.4
Share of elderly population (%)	19.1	5.3	7.6	34.1
Population density (persons/ha)	20.5	23.9	0.8	139.3
Per capita income (thousand yen)	1,356.3	274.2	677.3	2,627.4

4-4. Regression Results

Coefficients in a multiple regression model (5) were estimated using the cross-sectional data of 709 cities in 2000 for a residential sector and a transport (passenger) sector respectively. Regression results are shown in Table 4. Regression results for a residential sector show that temperature and per capita income are likely to have negative impacts on per capita CO_2 emissions in a residential sector at statistical significance level of 1%. They imply that the people in the cities with higher average annual temperature are likely to consume less electricity and heat at home and that the people with higher income are likely to consume less electricity and heat at home. A negative impact of per capita income on per capita CO_2 emissions in a residential sector is consistent with what is expected. Its possible reason is that the people with higher income have higher environmental awareness or afford to purchase energy-saving domestic goods or systems. An impact of population density is not statistically significant even at significance level of 10%. The share of elderly population is likely to have a positive impact on per capita CO_2 emissions in a residential sector at significance level of 5%. It implies that the cities with the higher share of elderly population are likely to have higher per capita consumption of electricity and heat. Its reason is discussed in detail in Section 5.

Regression results for a transport (passenger) sector show that temperature and population density are likely to have a negative impact on per capita CO_2 emissions in a transport (passenger) sector at statistical significance level of 5% and 1% respectively. A negative impact of population density on per capita CO_2 emissions in a transport (passenger) sector is consistent with what is expected. Its possible reason is that more compact cities with higher population density are likely to have better public transportation and that the people living in more compact cities drive less. Per capita income is likely to have a positive impact on per capita CO_2 emission in a transport (passenger) sector at significance level of 5%. An impact of the share of elderly population is not statistically significant at significance level of 5% (but statistically significant at significance level of 10%).

The figures of coefficient of determination (R^2) show that explanatory variables in a multiple regression model (5) can better explain a change in an explained variable (per capita CO_2 emissions) for a residential sector than for a transport (passenger) sector.

Table 4. Regression Results

(n=709cities)

		Residential		Transport (Passenger)	
		Coefficient	t-value	Coefficient	t-value
Constant	β_0	3.05931	36.64**	1.07892	5.71**
Temperature	β_1	-0.10037	-37.00**	-0.01374	-2.24*
Share of elderly population	β_2	0.00358	2.18*	0.00699	1.88
Population density	β_3	0.00034	1.00	-0.00889	-11.60**
Per capita income	β_4	-0.00021	-6.16**	0.00017	2.21*
R^2		0.70966		0.27520	

**Statistically significant at 1%. *Statistically significant at 5%.

5. Further Analysis on the Impacts of Aging Population on Urban Per Capita CO_2 Emissions

Regression results show that the share of elderly population is likely to have a positive impact on per capita CO_2 emissions in a residential sector under all other things held constant while it is less likely to have an impact on per capita CO_2 emissions in a transport (passenger) sector. This section makes a further analysis on the impacts of aging population on per capita CO_2 emissions in residential and transport (passenger) sectors, particularly on its mechanism, using the data of twenty government-designated cities (*Seirei-shitei-toshi* in Japanese) including Kitakyushu-city. Figures 9 and 10 show the per capita CO_2 emissions of twenty government-designated cities for 1990 and 2000 in a residential sector and transport (passenger) sector respectively. For all of twenty government-designated cities the per capita CO_2 emissions increased during 1990-2000 in a residential sector and also in a transport (passenger) sector.

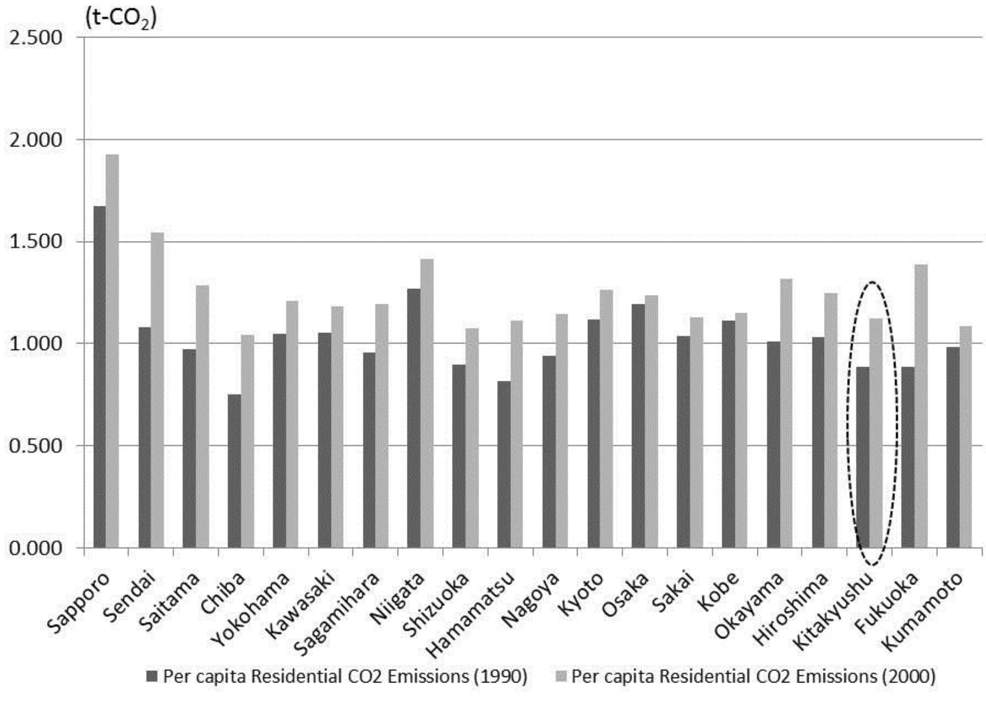

Figure 9. Per Capita Residential CO_2 emissions in 20 Gov't Designated Cities (1990 and 2000)

Data source: COLGEI 2007

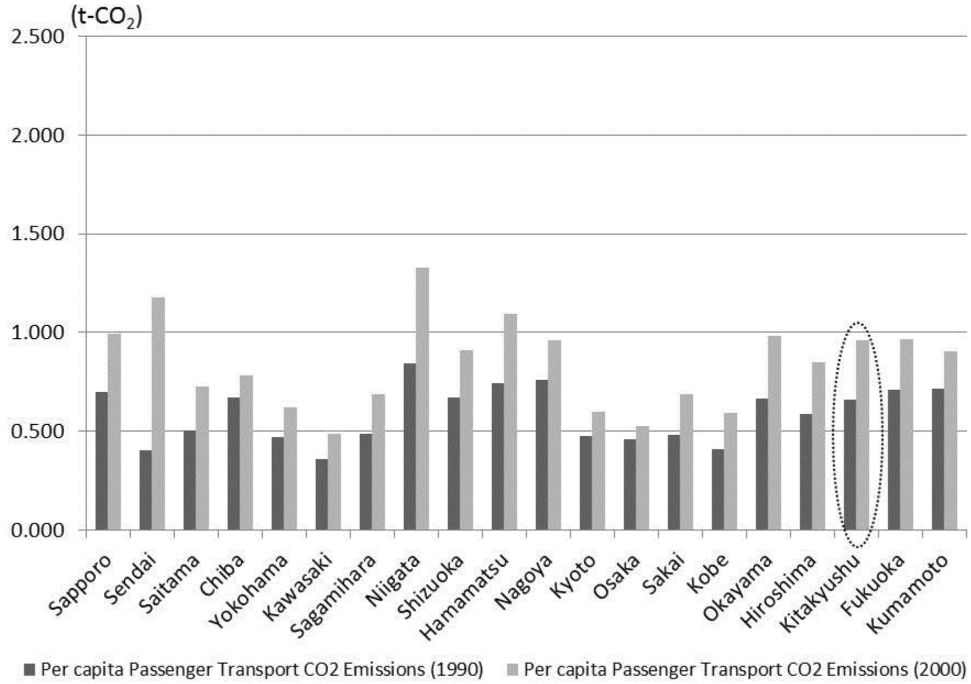

Figure 10. Per Capita Transport (Passenger) CO_2 emissions in 20 Gov't Designated Cities (1990 and 2000)
Data source: COLGEI 2007

During 1990-2000, the population increased for most of government-designated cities (16 out of 20) at a growth rate of 4.7% on average (Table 5). During the same period, the number of households also increased for all of government-designated cities. However, it increased at a higher growth rate of 17.3% on average compared to the growth rate in population. In particular, the number of elderly households (single and couple) increased at a remarkably higher growth rate of 100.2% on average during the same period. As a result, an average number of household members (= population ÷ the number of households) decreased for all of government-designated cities during the same period (Figure 11). A smaller number of household members suggests a less efficient use of electricity, heat, or gasoline at household. For example, the quantity of electricity used for lighting a room is the same regardless of the number of people in a room, or the quantity of gasoline used for driving an automobile is the same regardless of the number of passengers in an automobile.

Table 5. Population and Households of 20 Government-Designated Cities (1990 and 2000)

Name of Cities	Population			Households			Elderly households (single & couple)		
	1990	2000	Growth (%)	1990	2000	Growth (%)	1990	2000	Growth (%)
Sapporo	1,665,169	1,797,479	7.9	640,005	759,338	18.6	49,157	104,126	111.8
Sendai	912,108	1,007,628	10.5	334,834	420,368	25.5	20,229	41,932	107.3
Saitama	1,005,649	1,131,538	12.5	336,844	423,566	25.7	20,441	45,872	124.4
Chiba	824,034	883,008	7.2	278,884	345,488	23.9	15,298	39,456	157.9
Yokohama	3,203,195	3,414,860	6.6	1,149,740	1,353,526	17.7	77,203	170,430	120.8
Kawasaki	1,171,041	1,249,029	6.7	462,553	539,836	16.7	26,672	55,319	107.4
Sagamihara	601,057	681,100	13.3	206,559	261,924	26.8	9,457	23,407	147.5
Niigata	775,038	806,588	4.1	239,218	281,424	17.6	16,826	33,097	96.7
Shizuoka	739,073	729,739	-1.3	236,884	260,963	10.2	15,648	32,249	106.1
Hamamatsu	751,230	786,196	4.7	228,552	268,207	17.4	14,885	30,419	104.4
Nagoya	2,146,948	2,148,949	0.1	784,150	877,508	11.9	63,847	125,722	96.9
Kyoto	1,461,215	1,461,052	0.0	548,168	612,805	11.8	58,685	96,950	65.2
Osaka	2,603,789	2,595,394	-0.3	1,014,881	1,149,047	13.2	113,604	191,822	68.9
Sakai	843,743	828,098	-1.9	277,406	307,756	10.9	21,445	45,156	110.6
Kobe	1,466,546	1,492,143	1.7	530,063	604,290	14.0	61,348	106,972	74.4
Okayama	639,778	674,233	5.4	220,292	258,878	17.5	21,074	37,987	80.3
Hiroshima	1,088,951	1,132,660	4.0	403,103	461,444	14.5	36,422	64,274	76.5
Kitakyushu	1,022,737	1,010,127	-1.2	363,901	406,414	11.7	43,946	77,693	76.8
Fukuoka	1,229,865	1,336,662	8.7	483,712	594,861	23.0	35,597	69,051	94.0
Kumamoto	678,825	720,355	6.1	236,363	277,181	17.3	22,762	40,165	76.5
Average	-	-	4.7	-	-	17.3	-	-	100.2

Data source: e-Stat. Note: Growth rate (%) is the rate of increase in 2000 from the year of 1990.

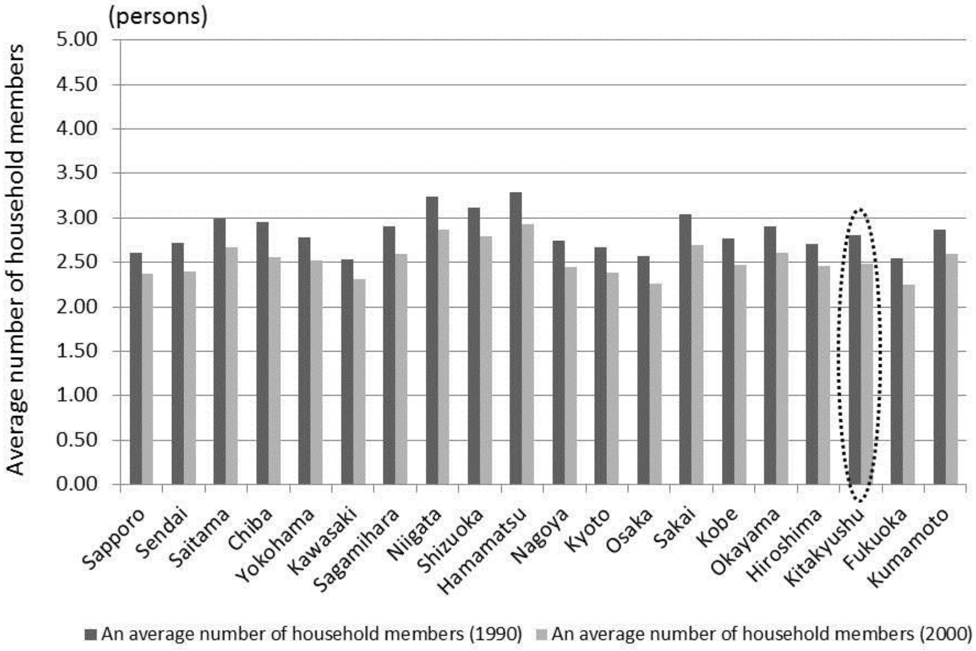

Figure 11. Average Number of Household Members in 20 Gov't Designated Cities (1990 and 2000)

Data source: e-Stat.

As a result, a smaller average number of household members implies larger per capita energy consumption and thus larger per capita CO_2 emissions. This can partly explains an increase in per capita CO_2 emissions in residential and transport (passenger) sectors during 1990-2000 for all of twenty government-designated cities as already shown in Figure 9 and 10. In sum, an increase in the share of elderly population is likely to increase per capita CO_2 emissions in residential and transport (passenger) sectors. This is consistent with the regression results particularly for a residential sector.

6. Conclusion

The summary of the study findings is the following.

Firstly, the projection on Japan's population and the number of households for the period of 2010-2030 (in Section 2) indicates:

① <u>Declining and aging population</u>:
A decrease in population with an increase in elderly population and its share

② Increasing elderly households:
An increase in the number of elderly households (single and couple) and its share in total number of households

③ Increasing number of households:
An increase in the number of households

④ Decreasing average number of household members (= population ÷ the number of households):

⑤ The share of elderly households is negatively highly correlated to the average number of household members (a correlation coefficient using the data during 1980-2035 is -0.988).

Secondly, regression results conducted to investigate the impacts of aging population on urban per capita CO_2 emissions in residential and transport (passenger) sectors using the data of 709 cities in 2000 (in Section 4) suggest:

An increase in the share of elderly population
⇩ (a partial impact)
An increase in per capita CO_2 emissions in residential sector at a significance level of 5% and in transport (passenger) sector at a significance level of 10%

Though there are other factors besides the share of elderly population, which have the impacts on per capita CO_2 emissions in two sectors, such as temperature, population density and per capita income, the regression result mentioned above is supported by analyzing a mechanism for the impacts of aging population on per capita CO_2 emissions based on the data of 20 government-designated cities in 1990 and 2000 (Section 5). The data of 20 government-designated cities show that per capita CO_2 emissions in two sectors increased during 1990-200 while the average number of household members decreased during 1990 and 2000 resulting from an increase in the number of households, particularly elderly households during the same period.

Theoretical framework (in Section 4) shows that a change in urban CO_2 emissions can be decomposed into two parts, a change in per capita CO_2 emissions and a change in urban population. Therefore, whether declining and aging population increases or decreases urban CO_2 emissions depends on the degree of its impact on per capita CO_2 emissions. As discussed, an average number of household members is crucial in determining per capita CO_2 emissions. Since an average number of household members (= population ÷ the number of households) is determined by population and the number of households, it is likely to decrease under declining and aging population as projected by NIES indicates. Furthermore, a predicted increase in the number of single households can be seen not only for elderly population but also working population in Japan (NIES). Therefore, there is a high possibility that CO_2 emissions in Japanese cities would increase under declining and aging population.

References

COLGEI (The Coalition of Local Governments for Environment Initiative), 2007, *Kankyo Jichitai hakusho 2007* (in Japanese), Seikatsusha, Tokyo, Japan.

MIAC (Japanese Ministry of Internal Affairs and Communications), e-Stat (Portal site of official statistics of Japan): http://www.e-stat.go.jp

National Institute for Environmental Studies (NIES), Greenhouse Gas Inventory Office of Japan, "The GHGs Emissions Data of Japan-1990-2011" (in Japanese, announced April 12, 2013): http://www-gio.nies.go.jp/aboutghg/nir/nir-e.html

National Institute of Population and Social Security Research, Population Statistics 2014: http://www.ipss.go.jp/syoushika/tohkei/Popular/Popular2014.asp?chap=0

National Institute of Population and Social Security Research, 2013, *Household Projections for Japan: 2010-2035* (in Japanese), Population Research Series No. 329.

O'Neill, B. C., Mackellar, F. L., and Lutz, W., 2001, *Population and Climate Change*, Cambridge University Press, Cambridge, UK.

United Nations, *World Population Prospects: The 2012 Revision*. http://esa.un.org/wpp/

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The Case of Japanese Cities

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