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Working Age Population and CO_2 Emissions in Indonesia: Household Approach

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Abstract. An increase in the working age population causes an increase in consumption which in turn will have an impact on increasing CO_2 emissions. The household is an element that must be responsible for increasing emissions of greenhouse gases because of their fossil fuels consumption. This study aims to observe the relationship of the working age population and the CO_2 emissions in households. This study use data from National Socio-Economic Survey (Susenas) 2019 with households consuming gasoline / diesel / kerosene for transportation, and LPG / kerosene for cooking as a unit of analysis. Apart from working age population as the main independent variable, socioeconomic characteristics (household size, income, residential area, poverty, age, sex, education, employment status, and access to modern fuels) are also used as control variables. Multiple regression analysis was used in this study. The results show that the working age population variable is positively correlated to total CO_2 emissions, transportation-related emissions, and cooking fuels emissions. Respectively, households dominated by members of working age (15-64 years) emitted 8.7%, 12.7%, 3.2% higher than households dominated by non working age (0-14 years and/or 65+ years). Providing sustainable transport system can be the best solution to reduce CO_2 emissions.

1. Introduction

Working age population (15-64 years) is the capital for development. Numerous and highly-qualified working age population can play a positive role in economic development [1]. The proportion of the productive age population in 2020 is projected at 68.7% of the total population, which equals 185.2 millions of people. That proportion has increased compared to previous years, and is predicted to continue to increase until 2021 and 2022 before starting to decline [2]. An increase in the proportion of the working age population indicates a transition in the age structure of the population. This transition occurs due to a demographic transition, namely changes in population caused by changes in birth rates and death levels. It started from an equally high birth rate and death level and to the final phase in which the mortality and birth rates are at their equally lowest level [3]. High birth rates in the past caused the growing number of youth (residents aged 0-14 years). Over time, the young population grows and enters the working age population, thus increasing the number of working age population. Meanwhile, at the end of the demographic transition, birth rates have fallen, so that the young population has declined. An increase in the working age population and a decrease in the young population causes the proportion of working age to increase.

An increase in the proportion of the working age population causes an increase in consumption. The consumption needs of the working age population are more than the non-working age population (young and old population), namely the consumption of tobacco, gasoline, clothing, food, cars and furniture [4]. Increased consumption of industrial products has an impact on increasing CO_2 emissions due to the use of fossil fuels in the process of producing these goods. Similarly, an increase in gasoline consumption for transportation can also increase CO_2 emissions. Whatever is consumed by households, either directly from nature or indirectly from the production process, generates emissions, and waste. Some of this waste is reprocessed or recycled into new products and some that are not reprocessed into nature [5].

CO_2 emissions are the biggest contributor to global greenhouse gas emissions. Global emissions increased from 2 billion tonnes of CO_2 in 1900 to more than 36 billion tonnes 115 years later [6]. CO_2 emissions account for 76% of greenhouse gas emissions, while the remaining 16% is contributed by methane, 6% from nitrous oxide and 2% from fluorinated gas [7]. Greenhouse gas emissions in Indonesia in 2017 increased by 14.5% from the condition in 2000. The energy sector was the biggest contributor to greenhouse gas emissions in 2017. The sector's contribution was 48.72% in 2017, an increase of 19.16% from its contribution at the year 2000 [8]. The increase in greenhouse gas emissions in the energy sector is caused by an increase in energy consumption. During the 2008-2018 period, energy consumption increased 45.22%, from 598 million BOE in 2008 to 868.6 million BOE in 2018 [9].

Household is the element that must be responsible for increasing emissions of greenhouse gases because of their fossil fuels consumption [10]. Nearly 75 percent of the world's greenhouse gas emissions are generated by households [11]. Research conducted by Hertwich and Peter [12] stated that 72 percent of greenhouse gas emissions in the world are generated by household consumption, 10 percent from government consumption, and the remainder from the investment sector. If seen from the type of goods consumed, food (20%), household operation and housing improvement (19%), and mobility (17%) are the biggest consumption of greenhouse gas emitters globally. Fuel consumption of private motor vehicles contributes the largest emissions to mobility. Meanwhile, Jones and Kammen [13] stated that the consumption of motor vehicle fuel as the biggest contributor to greenhouse gas emissions in American households, followed by electricity consumption and meat consumption.

In addition, socioeconomic characteristics such as household income, residential area (rural or urban), climate conditions, household size, and demographic factors (age, sex, population density, type of house) also affect the emissions produced [5]. Meanwhile, Tukker et al [14] explained factors that explain the diversity of environmental impacts by households including income, household size, location, vehicle ownership, diet, international and interregional trade, socio-cultural differences, geographical locations, and housing type. Druckman and Jackson [11] studied the characteristics of households that drive carbon emissions namely income, household size, employment status, location, housing characteristics, construction of the house, food, education, and socio-cultural differences.

Upon the basis of high CO_2 emissions phenomenon as a result of energy consumption and Indonesia's commitment to reduce emissions by 29%, it is necessary to conduct a study in relation to this. Research on the relationship between working age population and CO_2 emissions in Indonesia has been carried out, for example Abdurahman [15] examined the relationship at the national level in Indonesia. While, Nugrahayu et al [16] estimated CO_2 emissions from settlements in Yogyakarta at the household level. To the author's knowledge there are no studies linking working age population and CO_2 emissions at the household level. Thus, this research needs to be carried out as an attempt to try to fill the literature gap in the relationship between working age population and CO_2 emissions, especially at the household level.

Based on the manual for air emissions accounts (including CO_2), air emissions in households occur when the household performs activities that generate emissions such as fuel combustion when heating homes, or petrol combustion when driving a car [17]. So, CO_2 emission in household classify into three categories, that is transport, heating/cooling (include cooking), and other. Transport emission in household arises from the private use of motor vehicles, and also use private leisure boats and aircrafts. Heating/cooling emission in household is derived from the fuel combustion for cooking and producing hot water. Other emission in household includes solvent emission from paints, aerosol from sprays and emission from open fires (for leisure or burning garden refuse). Ahmad, Baiocchi, and Creutzig [18] conducted research on CO_2 emissions produced by urban households in India by classifying CO_2 emissions into three categories, namely emission from electricity, cooking fuel, and transportation.

The purpose of this research is to determine the relationship between working age population and CO_2 emission in households. The CO_2 emissions calculated in this research are limited to emissions come from fuel consumption for transportation and cooking. Emission from electricity purchased by household are not counted in our research. In addition, this study also uses socioeconomic characteristics (household size, income, poverty, residential area, age, sex, education, and others) as control independent variables.

2. Research Method

This research is an analysis of quantitative data using 2019 National Socio-Economic Survey (Susenas) data as the data source. The unit of analysis used is households that consume gasoline / diesel fuel / kerosene for transportation, and LPG / kerosene fuel for cooking. Of 315,672 samples in Susenas, 222,788 households met the requirements for this study. CO_2 emissions were set as the dependent variable in this study. The calculation of CO_2 emissions in this study follows the guidelines from the International Panel on Climate Change (IPCC) Guidelines established by the United Nations (UN) [19] and the Guidelines for the Implementation and Reporting of Greenhouse Gas Inventories [20] as stipulated in the Ministerial Regulation Number P.73/MenLHK/Setjen/Kum.1/12/2017 dated 29 December 2017 [21]. Based on the two guidelines, the calculation of CO_2 emissions is as follows:

$$emissions_{GHG,F} = AD_F \ x \ EF_{GHG,F} \quad (1)$$

In which $emissions_{GHG,F}$ expresses designated greenhouse gas emissions (in this study, carbon dioxide emissions) by type of fuel (Kg CO_2), AD_F expresses activity/consumption data by type of fuel (TJ), and $EF_{GHG,F}$ expresses greenhouse gas emissions (carbon dioxide) factor by fuel type (kg CO_2/ TJ).

Table 1. Calorific Value and Emission Factor for Each Fuel

Fuel Type	Unit	Calorific Value	Emission Factor
Gasoline	Liter	3.3E -05 TJ / liter	69300
Solar (Diesel fuel) / ADO	Liter	3.96E-05 TJ / liter	74100
Kerosene	Liter	3.62E-05 TJ / liter	71900
LPG	Kg	5.20E-05 TJ / Kg	63100

Source: Regulation of the Director General of PPI (22), and IPCC (19)

The calculation of carbon dioxide emissions in this study uses the tier 1 method because no specific emission factor data is available in Indonesia, so it uses the default emission factor given in the 2006 IPCC guideline. Since the available data was in the form of a quantity of fuel in units of volume / weight (liters / kg), it requires the conversion of units of the calorific value data for each fuel from the unit of volume / weight to units of energy (TJ). This calorific value was taken from the guidelines from KLHK [20]. So, the calculation of AD_{BB} is as follows:

$$AD_F = \ C_F \ x \ NCV_F \quad (2)$$

Which C_F is fossil fuel consumption from household (liters or kg) whose data is sourced from National Socio-Economic Survey; and NCV_F was the calorific value according to type of fuel (TJ). By substituting equation (2) into equation (1), the calculation of CO_2 emissions is obtained as follows:

$$emissions_{GHG,F} = C_F x \ NCV_F \ xEF_{GHG,F} \quad (3)$$

The calorific values and emission factors used was presented in Table 1.

Ahmad, Baiocchi, and Creutzig [18] divide direct CO_2 emissions in households into 3 sources, namely electricity, cooking fuels, and transportation. This research focuses on 2 sources of direct CO_2 emissions in households, namely cooking fuels and transportation. The emissions from cooking fuels are emissions resulting from burning fuel for cooking purposes while the emissions from transportation are emissions from the use of fuel for transportation. Cooking fuel in this study is limited to 2 fuels, namely LPG and kerosene and the fuel for transportation in this study is limited to 3 fuels, namely gasoline, diesel, and kerosene.

In addition to the working age population variable as an independent variable, this study also uses the characteristics of the household and selected household heads as the control variable. The operational definitions of variables can be seen in Table 2.

Table 2. Operational definitions of variables used.

Variables	Notation	Description	Information
CO2 Emissions	LN_EMISI	CO2 emissions in household	CO2 equivalent
Working age population	PROD	Ratio of household members aged 15-64 years	1 if ratio over 50%; 0 if ratio 50% and under
Household size	HHSIZE	Number of household members	persons
Income	LN_EXP	average household spending per month	IDR
Poverty	POOR	households under the provincial poverty line	1 if non-poor; 0 if poor
Residential area	RES	Territory household residence	1 if urban; 0 if rural
Age	AGE	Head of household (KRT) age	years
Sex	SEX	Gender of head of household	1 if female; 0 if male
Education	EDUC	Highest education of the head of the household	1 if Middle school; 0 if others 1 if High school / vocational high school; 0 if others 1 if Diploma and above; 0 if others
Employment Status	WORK	Whether the head of the household is working.	1 if working; 0 if non-working,
Access to modern fuels	COOK	Main fuel used by households for cooking	1 if kerosene; 0 if LPG 1 if besides kerosene and LPG; 0 if LPG

To determine whether there is a relationship between working age population and CO_2 emissions, this study uses a multiple regression model with dummy variables. Using this model, we follow previous research that links emissions with various types of determinants through the regression model presented as in equation 3 [18].

$$E_i = \alpha + \sum_{j=1}^{k} \beta_j X_{ji} + \varepsilon_i \quad (4)$$

In which i = 1, ..., N denotes the household, E_i denotes CO_2 emissions produced by households and X_{ji}, for j = 1, ..., k, shows the independent variable as a determinant of emissions, k is the total number of emission determinants, and ε_i is the error term. The empirical model in this study adjusted for equation 3, as follows:

$$LN\_EMISI_i = \alpha_0 + \beta_1 PROD_i + \beta_2 HHSIZE_i + \beta_3 LN\_EXP_i + \beta_4 POOR_i + \beta_5 RES_1 + \beta_6 AGE_i + \beta_7 SEX_i + \beta_8 EDUC_{1i} + \beta_9 EDUC_{2i} + \beta_{10} EDUC_{3i} + \beta_{11} WORK_i + \beta_{12} COOK_{1i} + \beta_{13} COOK_{2i} + \varepsilon_i \quad (4)$$

Equation (4) above is used to calculate each type of CO_2 emissions, namely from cooking fuels and transportation. Total CO_2 emissions are the sum of CO_2 emissions from cooking fuels and CO_2 emissions from transportation. Meanwhile, the main research hypothesis is that the working-age population is positively correlated to CO_2 emissions. Similarly, for the control variables, each control variable is thought to have a positive relationship with CO_2 emissions.

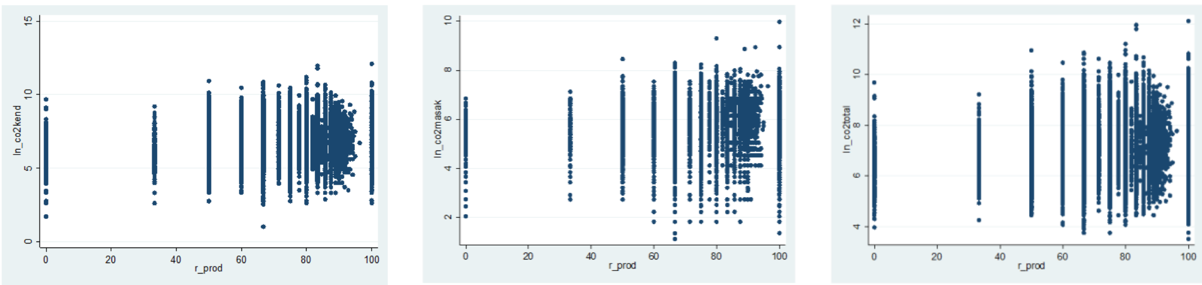
3. Result and Discussion

3.1. Sample characteristics

The unit of analysis in this study is households that consume gasoline / diesel fuel / kerosene for transportation, and consume LPG / kerosene for cooking, a total of 222,788 households from the whole dataset. A general description of the characteristics of the analysis unit is shown in Table 3. In general, most households that constitute the analysis unit consist of 4 to 5 household members. Most households are dominated by members of working age (the ratio of working age compared to non-working age is more than 50%). In other words, in a household, there are more working age household members compared to non-working age (children less than 15 years old and elderly more than 65 years old). Most of the samples are also non-poor households (94.53%), living in rural areas (53.91%), having male heads of households (89.44%) and working heads of households (97.28%).

3.2. Patterns of CO_2 emissions according to working age population

This description of CO_2 emissions patterns can be used to estimate the relationship graphically between CO_2 emissions with working age population. The working age population in this study was measured by the ratio of household members who were of working age (15-64 years). In general, the average pattern of CO_2 emissions by the working age population shows a positive relationship (see Figure 1). The greater the ratio of the working age population (the more members of the working age household in one household), the greater the CO_2 emissions produced. The average pattern of total, transportation, and cooking CO_2 emissions fluctuates. The average total CO_2 emissions produced by households is the highest when the ratio of working age population ranges from 81% to 90%. When compared between the ratio of working age population of less than 50% and more than 50%, it was found that the average total, transportation and cooking CO_2 emissions produced by households with a ratio of working age members more than 50% are higher. Of the two types of emission sources, the average CO_2 emissions from transportation are higher than emissions from cooking fuels.



a. transportation emission   b. cooking fuel emission   c. total emission

Figure 1. Relationship between CO_2 emissions and the ratio of working age household members

Table 3. Sample characteristics

Variable	Mean	Std dev	Min	Max
Working Age Population	79.98	14.77	0	100
Household Size	4.05	1.60	1	34
Income (Natural Logarithm)	15.18	0.60	12.67	19.30
Poverty	0	0.23	0	1
not poor (%)	94.53			
poor (%)	5.47			
Residential area	0	0.50	0	1
rural (%)	53.91			
urban (%)	46.09			
Age	47.49	12.25	12.00	97.00
Sex	0	0.31	0	1
male (%)	89.44			
female (%)	10.56			
Education	8	5.59	0	22
Did not finish elementary school (%)	2.45			
Elementary school / equivalent (%)	27.14			
junior high school / equivalent (%)	16.93			
high school / equivalent (%)	28.05			
Diploma and above (%)	25.43			
Employment Status	1	0.16	0	1
not working (%)	2.72			
working (%)	97.28			
Access to modern fuels	1,26	0,60	1	3
LPG (%)	0.64			
Kerosene (%)	4.47			
Others (%)	94.89			

3.3. Relationship of working age population and socioeconomic characteristics to CO_2 emissions

The results of the regression analysis showed that the working age population variable is positively correlated to total CO_2 emissions, CO_2 emissions from transportation and cooking fuels (Table 4). Households dominated by members of working age (15-64 years) produced 8.7% higher total CO_2 emissions than households dominated by non-working age members (0-14 years and or 65 years and above). Likewise, with CO_2 emissions from transportation and cooking fuels, households dominated by working age members produced higher CO_2 emissions from transportation by 12.7% and from cooking fuels emissions by 3.2% than households dominated by non-working age members. When compared between transportation emissions and cooking fuels emissions, emissions from transportation produced by the working age population are higher than from cooking fuels emissions. This is in accordance with the behavior of the working age population who prefers to spend time outside the home such as traveling and hanging out in a café. That behavior has an impact on household expenditure that is dominated by members of the working age so that household expenditure for transportation fuel is more than cooking fuel expenditure. Households that are dominated by non-productive ages such as children tend to have reduced fuel consumption for transportation and divert it to consumption of other goods such as electricity for heating instead [23]. Similarly, for households dominated by household members aged 65 years or more, they consume less fuel for transportation and increase electricity consumption because they prefer to spend time at home [24].

The socioeconomic characteristics used in this study also indicate a relationship with CO_2 emissions generated even though some variables' direction is not as expected. Household size is positively correlated to total, transportation, and cooking fuels CO_2 emissions. The greater the size of the household (the more household members it has), the greater the emissions produced. When household size increases by a person, total emissions will increase by 2.4%, transportation emissions will increase by 0.5%, and cooking fuels emissions will increase by 7.7%.

Table 4. Results of multiple regression analysis

Variables (Notation)	Transportation		Cooking fuels		Total	
Working age population (PROD)	0.127	***	0.032	***	0.087	***
> 50% (ref: <=50%)	(0.007)		(0.005)		(0.005)	
Household size (HHSIZE)	0.005	***	0.077	***	0.024	***
	(0.001)		(0.001)		(0.001)	
Income (LN_EXP)	0.729	***	0.148	***	0.572	***
	(0.004)		(0.002)		(0.003)	
Poverty (POOR)	0.004		-0.111	***	-0.001	***
Poor (ref: not poor)	(0.007)		(0.005)		(0.005)	
Residential Area (RES)	0.028	***	0.069	***	0.047	***
Urban (ref: rural)	(0.003)		(0.002)		(0.002)	
Age (AGE)	0.001	***	0.006	***	0.003	***
	(0.000)		(0.000)		(0.000)	
Sex (SEX)	-0.060	***	-0.038	***	-0.056	***
Female (ref: male)	(0.005)		(0.004)		(0.004)	
Education (EDUC)						
Middle School (ref : elementary School)	0.003		0.026	***	0.008	***
	(0.004)		(0.003)		(0.003)	
High School / Vocational School (ref : elementary School)	0.040	***	0.021	***	0.031	***
	(0.004)		(0.003)		(0.003)	
Diploma and above (ref : elementary School)	0.170	***	0.039	***	0.139	***
	(0.006)		(0.004)		(0.004)	
Employment Status (WORK)	0.257	***	0.087	***	0.183	***
Works (ref: not working)	(0.010)		(0.008)		(0.007)	
Access to modern fuel (COOK)						
Kerosene (ref: LPG)	-0.224	***	0.303	***	-0.035	***
	(0.006)		(0.005)		(0.004)	
Others (ref: LPG)	-0.121	***	-0.573	***	-0.245	***
	(0.005)		(0.005)		(0.004)	
Constants	-5.225	***	2.531	***	-2.439	***
	(0.051)		(0.035)		(0.040)	
n	222,788		222,788		222,788	
R squared	0.317		0.243		0.377	
adj R squared	0.317		0.243		0.377	
F stat	6940,99	***	4228.87	***	8565.89	***

***, **, and * denotes as significant at 1% level, 5% level, and 10% level
The value in (….) indicates robust standard error

Income is positively and strongly correlated to CO_2 emissions. Moreover, income is one of the most important determinants of carbon flow balances [11]. The results of this study indicated that the higher the income, the greater the CO_2 emissions produced. When household income increased by 1%, it increased total emissions by 0.57%, transportation emissions by 0.73% and cooking fuels emissions by 0.15%. The results of this study are in line with the results of previous research that the effect of income on emissions is most sensitive to emissions from transportation [18][25]. Emissions from private vehicles are the most sensitive changing emissions with an increase in income [18]. In addition, the increase in emissions along with an increase in income also shows an increase in energy needs [24]. Increased energy requirements for transportation indicate an increase in mobility and also poor public transportation infrastructure.

The relationship of poverty to CO_2 emissions differs depending on what type of fuel is consumed. In fuel consumption for transportation, poor households produce 0.4% more CO_2 emissions than non-poor households. Whereas in terms of consumption of cooking materials, poor households emit CO_2 11% less than non-poor households. Poor households prioritize the consumption of transportation fuel to go to work for money.

The residential area is positively correlated to CO_2 emissions. Households living in urban areas produce cooking fuels emissions 6.9%, transportation emissions 2.8%, and total emissions 4.7% more than those living in rural areas. These results are in line with research by Zhang et al [26], as urban communities consume more energy than rural communities [27][28].

The age variable has a positive relationship with CO_2 emissions from transportation, cooking fuels emissions, and total emissions. The older the head of the household, the higher the emissions is [18]. A year increase in age will increase CO_2 emissions from transportation by 0.1%, cooking fuels emissions by 0.6%, and total emissions by 0.3%.

The sex variable in this study is negatively correlated to emissions. Female household heads produced less CO_2 emissions than male household heads by 6%, 3.8%, 5.6% for transportation, cooking fuels, and total emissions, respectively. However, when compared between transportation and cooking fuels, CO emissions produced by female heads of households are more sensitive to fuel consumption for transportation [29][23]. Men consume more energy for transportation because they spend more on vehicle operating costs such as purchasing fuel, spare parts, and repair costs and vehicle maintenance [29]. Likewise, female heads of household produce lower transportation emissions due to lower motor fuel expenditure but produce more emissions on the use of residential energy (electricity and gas) [23].

Educational variables have a positive relationship with the CO_2 emissions produced. The higher the education, the greater the CO_2 emissions produced. Compared to elementary and non-school education, heads of households with junior high school education produced total emissions of 0.8% more, high school education 3.1% higher, and diploma education above 13.9% more. These results are similar to studies conducted by Underwood [30], and Ye et al [31]. Increase in education, increase in indirect energy expenditures [30].

Employment status has a positive relationship with CO_2 emissions. The working heads of household will produce higher transportation emissions by 25.7%, cooking fuels emissions by 8.7%, and total emissions by 18.3% than heads of households who did not work. People who work need more energy [24]. While people who do not work produce less CO_2 emissions from transportation does not mean they do not do activities outside the home but they use more public transportation [23]. When compared between consumption for transportation and cooking fuels, people who work produce CO_2 emissions more for transportation than for cooking fuels. People who work consume more fuel for vehicles than electricity and cooking fuels because they spend more time outside the home, especially at work or in vehicles [24].

In general, modern cooking fuel access variables have a positive relationship with CO_2 emissions. Households that do not have access to modern fuels (LPG) but have access to kerosene produce 3.5% less total emissions, 22.4% less transportation emissions, and 30.3% higher cooking fuels emissions when compared to households that have access to LPG fuel. These results are similar to the results of Ahmad et al [18]. Households that have access to modern fuels have greater vehicle fuel consumption patterns. The interesting thing in this study is that there are still households that do not have access to modern fuels (LPG) so that they still use kerosene as the main cooking fuel. In fact, the kerosene to LPG conversion program has long been established since 2007. However, to date the distribution of LPG has not been evenly distributed throughout the region. Eastern Indonesia, especially Maluku and Papua, have not had much access to modern fuels. This is caused by constraints in infrastructure, geographical location, and physical access [32]. The LPG distribution terminal by Pertamina only reaches 44% of the sub-district in Indonesia, which is around 7,058 sub-districts.

4. Conclusion

This study found that the working-age population is positively correlated to total emissions, transportation emissions, and emissions from cooking fuels. However, changes in CO_2 emissions from transportation are more sensitive to differences in the ratio of working age population. The behavior of the working age population, who prefer activities outside the home, is suspected to be the cause of sensitivity to CO_2 emissions from transportation. Meanwhile, socioeconomic characteristics are also positively correlated to CO_2 emissions such as household size, income, residential area, age, education and employment status. While poverty, sex, and access to modern fuel variables are negatively correlated to CO_2 emissions.

Considering the results of this study and the target of reducing greenhouse gas emissions by 29% in 2030, the government needs to be aware of the impact the booming population of working age has, especially on the environmental aspects. By considering the behavior of the working age population, the government is expected to provide sustainable transport system for all, improving road safety, notably by expanding public transport. Using electric cars or motorcycles can be one of the solutions that can make cities and human settlement sustainable.

This research is limited to fuels used for transportation and cooking fuels. Future studies could broaden the scope of the studies. An example of it was how CO_2 emissions are generated from electricity as the use of electricity becomes an integral part in daily life.

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