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# Analysis of Carbon Dioxide Emission from Transportation Sector using Panel Data Method

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ANALYSISOFCARBONDIOXIDEEMISSIONFROMTRANSPORTATIONSECTORUSINGPANELDATAMETHOD

*Strictly as per the compliance and regulations of:*

# Analysis of Carbon Dioxide Emission from Transportation Sector using Panel Data Method

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*Abstract-* $CO_2$ emissions and climate change have become a topic of global importance for the international community, which should have led to immediate action to remedy this dangerous situation. The main objective of this work is to identify the causes and factors that can contribute to the reduction of $CO_2$ emissions in the transportation sector. The estimation method based on Panel data for 25 countries around the world has shown that the density of the urban population and the heavy use of private vehicles in many metropolitans are the main causes of $CO_2$ emissions. We have demonstrated that the development of renewable energies, the development of collective transport systems and sustainable forest management practices are concrete and practical solutions to fight against $CO_2$ emissions in megalopolises.

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## I. Introduction

Each year, several tones of $CO_2$ (carbon dioxide) are released into the atmosphere, accelerating the rise in temperatures around the world. These greenhouse gas emissions are mainly due to the consumption of fossil fuels, oils, gases and which are linked to various human activities. The transport sector is the second largest contributor to the increase in the atmospheric concentration of $CO_2$. The use of transport requires the combustion of fossil fuels, which increases the volume of carbon dioxide emitted into the atmosphere. Several factors are taken into account to determine the carbon footprint of land transport such as population density, urbanization, and distance traveled, type of journey and number of passengers. According to the study conducted by the OECD (Organization for Economic Co-operation and Development) in 2018, transport accounts for 24.4% of the share of global emissions behind the production of heating and electricity, which represents 41.5% of emissions from greenhouse gas around the world. The figures show that $CO_2$ emissions from the transport sector have steadily increased over the past decade despite tangible efforts by some countries to reduce pollution and environmental impact. This development is likely to continue if we have not found an alternative to fight against this scourge. To curb the increase in $CO_2$ emissions in the transport sector, the public authorities are obliged to take more determined action to improve the current situation. The main objective of this work is to identify the causes and factors that can assist in reducing the production of $CO_2$ emissions and to contribute in proposing recommendations that could be applied to future programming.

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## II. Literature Review

The increase in greenhouse gas emissions, especially $CO_2$ emissions, is the cause of global warming. However, when we analyze the growth curve of $CO_2$ in the atmosphere, we observed a very rapid growth, which began in the 2000s. Indeed, the reduction of $CO_2$ emissions from transport is a subject of concern. This subject has been deeply analyzed at the scientific level. For example, the researchers have shown that $CO_2$ emissions from freight transport can be analyzed using 7 key indicators; the modal split, the number of handling operations in the transport chain (handling factor), the distance of the trip (length of haul), the weight of the load (payload on laden trips), the proportion of empty trips (proportion of km run empty), energy efficiency (energy efficiency), the carbon intensity of the energy used (carbon intensity of the energy source). These parameters could be used as a basis for developing and implementing policy measures towards global efforts to reduce $CO_2$ emissions from freight transport. The author also proposed measures such as reducing the number of handling operations, reducing the distance of the journey to reduce freight demand, developing less carbon-intensive modes of transport, improving the filling rate; increase the energy efficiency of road transport [1]. In addition, for the world to stay within the safe threshold of a 2 ° C increase in average temperature agreed to by virtually all governments, the transport sector must be carbon-free. The author has shown that the two main obstacles that have prevented $CO_2$ emissions reductions are the absence of a legally binding global agreement and the high relative cost of clean vehicle/energy techniques [2]. Furthermore, researchers have shown that the transportation sector is a major contributor to greenhouse gas emissions, accounting for about 20 percent of all carbon dioxide emissions globally, and road transport accounts for the vast majority of these emissions [3]. Global warming and climate change have been two hotly debated topics lately due to their malicious consequences not only on ecosystems, but also on the human race. The levels of $CO_2$ emissions are on the rise again and the objectives set at the

COP21 Paris 2015 are becoming almost impossible to achieve [4]. In 1990, CO2 levels in the atmosphere were 354.4 ppm, but by 2018 this level had risen to 408.5 ppm. This means, the CO2 emissions levels from fossil fuels reached a record high of 37.1 gigatones. To reach the Paris target of 2 ° C, global carbon emissions will need to be reduced by 50% by 2030 and to zero by 2050. Over time, to meet the set targets at the macro level, the state could use public instruments and resources such as taxes, the pricing system, develop the modal shift by favoring soft modes, the establishment of standards relating to pollution and noise, encouraging the uptake of eco-labels and to promote sustainable forest management [5].

## III. Research Methodology

The specificity of our work lies in the choice of developing countries and developed countries as the field of investigation, 25 countries were selected to analyze the impact of urbanization variables, population and the transport system on emissions of CO2 from transport over a 49-year period (1970 to 2018). The choice of countries depends on the availability and reliability of quality data.

We have selected European countries and territories such as; Belgium: BEL, Switzerland: CHE, Germany: DEU, France: FRA, Turkey: TUR.

African countries; Angola: AGO, Cote d'Ivoire: CIV, Cameroon: CMR, Algeria: DZA, Morocco: MAR, Tunisia: TUN.

America countries; Argentina: ARG, Bolivia: BOL, Brazil: BRA, Canada: CAN, Chile: CHL, Cuba: CUB, United States: USA.

Asian countries; United Arab Emirates: ARE, India: IND, Japan: JPN, Malaysia: MYS, Saudi Arabia: SAU, China: CHN.

And finally Australia: AUS.

Three variables are needed to assess the CO2 emissions from transport. First, the population is a key factor in determining the assessment of CO2 from transportation. Cities concentrate economic activity, and energy consumption for housing, transport, infrastructure. More than half of the world population lives in cities, the metropolises contribute more CO2 emissions at the planetary level. Urbanization and population continues at an accelerated pace, particularly in developing countries, but also with the expansion of urbanized territories. Two indicators were used to measure the evolution of urbanization and population, such as population density and urban population growth. Subsequently, we proposed that the urban planning reorganization and the town planning structure could reduce the percentage of CO2 emissions. We have proposed that the possible contributions of the green areas can combat CO2 emissions. In our case, two indicators were used to measure the contribution of agriculture and forestry such as forest area and agricultural land. Finally, the use of private transport is a direct source for a growing share of CO2 emissions produced by the combustion of energy. On the other hand, an efficiently designed and implemented a public transport system offers a practical mode of travel that reduces the need for private vehicles, and thus reduces CO2 emissions per passenger-km traveled. Two indicators were used to measure the evolution of the transport system such as the number of travelers by road and the number of travelers by railway transport services. Table 1 shows all the variables and indicators used in our context.

*Table 1:* The Variables used in the Panel model

| Indicator (unit) | Explication | Source |
|---|---|---|
| CO2 emissions from transport (% of total fuel combustion) | CO2 emissions from transport contains emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation [6]. | https://donnees.banquemondiale.org/indicator/ EN.CO2.TRAN.ZS |
| Population density (people per sq. km of land area) | Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status [6]. | https://data.worldbank.org/indicator/EN.POP.DN ST |
| Agricultural land (% of land area) | Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures [6]. | https://data.worldbank.org/indicator/AG.LND.AG RI.ZS |
| Forest area (% of land area) | Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural [6]. | https://data.worldbank.org/indicator/AG.LND.FR ST. ZS |

| | | |
|---|---|---|
| Road passengers (million passenger-kilometers) | Passenger transport refers to the total movement of passengers using inland transport on a given network. Data are expressed in million passenger-kilometers, which represents the transport of a passenger for one kilometer. [6]. | https://data.oecd.org/transport/passenger-transport. htm |
| Railways passengers (million passenger-km) | Passengers carried by railway are the number of passengers transported by rail times kilometers traveled [6]. | https://data.worldbank.org/indicator/IS.RRS.PASG. KM |
| Urban population growth (annual %) | Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects [6]. | https://data.worldbank.org/indicator/SP.URB.GROW |

Our study takes place over a long period (1970-2018) and based on a large number of observations (1225 for the sample with 49 observations for each indicator and for each country). This data collection is essential to analyze the behavior of countries and measure the impact of each variable with the use of artificial intelligence and more precisely with the Panel data method. The Panel data model has a number of advantages. The double dimension of the data (individual: country and temporal: years) makes it possible to implement a monitoring algorithm which simultaneously takes into account the dynamics of behaviors and their possible heterogeneity between the countries. It constitutes an advantage over other types of method such as time series and analytic data.

## IV. Panel Data

The data used in artificial intelligence are most often provided by a time series. Furthermore, it is possible to have instantaneous cross-sectional data relating to a given period. Therefore, the panel data model is written as a double index (*i*: individual and *t*: temporal) model which takes the following form Eq1:

$$Yit = \alpha + \beta \, Xit + \varepsilon it \qquad (1)$$

- *Yit* is the dependent variable (CO2 emissions from transportation)
- $\alpha$ is the intercept
- $\beta$ is the regression coefficient*Xit* is the independent variable (Population density, Agricultural land, Forest area, Road passengers, Railways passengers and Urban population)
- $\varepsilon$ is the error term

The dual dimension offered by panel data is a major advantage. Indeed, while time series data allow us to study the evolution of relationships over time, they do not allow us to control for unobserved heterogeneity related to individuals. Conversely, cross-sectional data make it possible to analyze the heterogeneity between individuals, but they cannot take into account the dynamic behavior. Thus, by using panel data, we can exploit the two sources of variation in statistical information: Temporal where intra-individual variability (within) Individual or inter-individual variability (Between) The increase in the number of observations makes it possible to guarantee better precision of the estimators, to reduce the risks of multi-collinearity and to widen the scope of the investigation. The panel considered is not necessarily complete (balanced data) where all statistical units are observed during the period considered. This may be an incomplete, unbalanced panel where individuals are not observed over the entire period of analysis due to the input/output problem.

## V. Result and Discussion

Between 1970 and 2018, global CO2 emissions from transport increased by 45% as indicated in Figure 1 and can be expected to increase by around by 70%. This trend is particularly marked in developing countries and emerging economies compared to developed countries. For example Brazil, Bolivia and Ivory Coast have more CO2 emissions due to transport compared to Australia and Canada.

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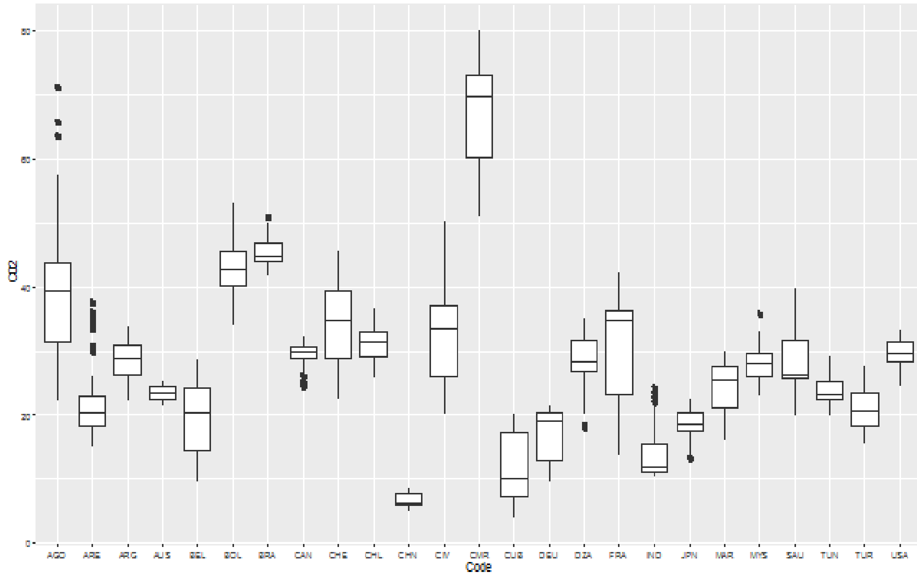


*Fig. 1:* The evolution of C02 emissions in the world for the period (1970 to 2018).

Figure 2 illustrates the distribution of population density for all selected countries. The figures show that the high population density of the countries combined with the dynamics of urbanization will translate into strong growth in demand for travel. Urban mobility here represents a significant part of this growth perspective. The high density is noticed especially in the developed countries compared to the developing countries. For example, we have noticed a high density of the urban population in France, Japan and Belgium.

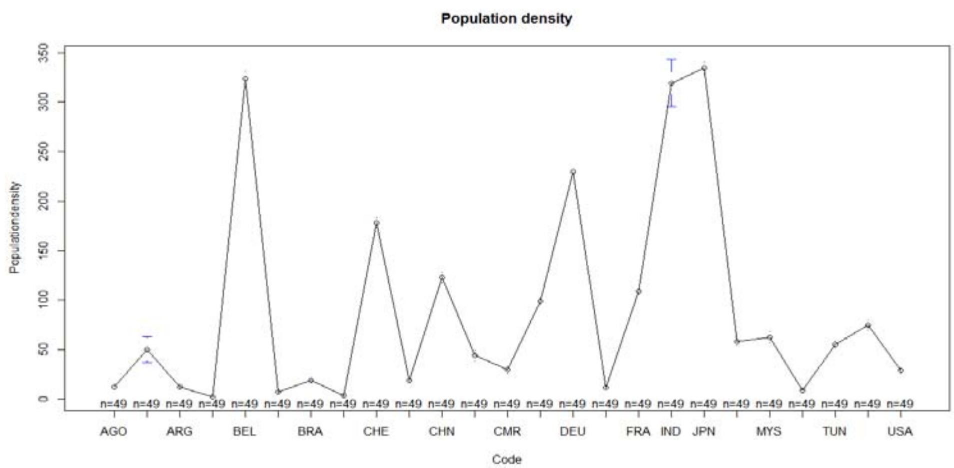


*Fig. 2:* The evolution of urban population in the world for the period (1970 to 2018).

The results of the panel model are shown in Table 2. We noticed that the population density exerted a positive impact (z-value> 0) and significant at 95%, this indicates that an increase in the population density recorded an increase in CO2 to 0.89% (coefficient of regression). Population growth to be the cause of environmental damage and CO2 emissions. This relationship is very obvious. Lifestyles are constantly changing, especially under the dynamic impetus of population, including higher living standards, technical progress and urbanization, in this case, the movement of displacement can become more and more polluting. Usually, the emphasis is precisely on technical progress to assert that the population growth and urban density of the population can be attributed largely to an increase in polluting emissions. In other words, an increase in population and an increase in population growth of 1% generate an increase of approximately 1.2% in CO2 emissions. Data for 25 countries between 1970 and 2018 show that the elasticity of carbon dioxide to population growth and population density is between 1.2 and 0.89.

In most cases, the rapid expansion of cities occurs in the absence of a land use planning strategy. Human pressure, thus generates extremely harmful effects on forests and landscapes, as well as on green spaces in cities. The environmental impacts of urbanization are often exacerbated by climate change and lead to increased pollution, decreased food and available resources and the frequency of extreme climate events.

We also noticed that the agricultural land and forest area variables had a negative and significant impact. For this reason, we have shown that planting green areas and trees can reduce CO2 emissions from transport by 1%. Tree planting projects, less expensive and easy to implement, have become very common to the point that all actors (companies, associations, local authorities, institutions, etc.) can reduce polluting activities and waste emissions from the transportation sector. The forests and wooded areas in cities (rows of trees, isolated trees, urban forests, etc.) are urban ecosystems providing various ecosystem services. Urban trees can help mitigate negative effects and social consequences of urbanization, and therefore make cities more resilient to these changes. In this sense, they constitute multifunctional spaces and can also be considered as natural actions to fight against environmental risks and adapt to climate change. In addition, these ecosystems can provide other services such as the contribution of biodiversity (animal and plant), the improvement of the living environment, the offer of recreational activities and the structuring of the landscape.

Finally, we have shown that the use of private vehicles in an exhaustive way can increase CO2 emissions to 3% and the use of public transport such as the train for example can reduce CO2 emissions by up to 0.14%. This implies that the two main environmental nuisances of the automobile are air pollution and the emission of greenhouse gases. In addition to air pollution, there is noise pollution, which would also have a significant impact on health [7]. An efficiently designed and implemented public transport system offers a practical mode of travel that reduces the need for private vehicles, thus reduces CO2 emissions, and the emissions produced per passenger-km traveled. Therefore, public transport promotes urban densification and also serves to reduce the distances should be traveled.

*Table 2:* The result of panel data

| Coefficients: | Estimate | Std. Error | z-value | Pr(>\|z\|) |
|---|---|---|---|---|
| (Intercept) | 2.9881e+01 | 4.8012e+00 | +6.2237 | 4.856e-10 *** |
| Population density | 8.9329e-02 | 1.2889e-02 | +6.9306 | 4.190e-12 *** |
| Population growth | 1.2953e+00 | 3.6041e-01 | +3.5940 | 0.0003256 *** |
| Agricultural land | -6.2576e-01 | 6.6513e-02 | -9.4081 | < 2.2e-16 *** |
| Forest area | -3.3879e-01 | 1.2460e-01 | -2.7191 | 0.0065459 ** |
| Railways passengers | -1.4761e-01 | 6.0694e-06 | -2.4321 | 0.0150113 * |
| Road passengers | 3.2020e+00 | 3.2912e-07 | +0.9729 | 0.0330594* |

*Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

## VI. The Performance of the Panel Model

The panel method makes it possible to take into account any unobservable factors specific to each pair of countries (so-called individual or specific effects). The Hausman test is used to test whether or not there is a correlation between the specific effects and the explanatory variables of the model. This makes it possible to choose between the fixed effects model and the random effects model [8]. The result of the Husman test showed that the test is significant (p-value 5%), for this reason, we retained the estimators of the fixed-effects model which is presented in table 2, thus envisaging the errors are not correlated with the regression coefficient. This statistic is asymptotically distributed according to a chi-square equal to 2289.8 with 6 degrees of freedom, it is the number of variable introduced in the model.

## VII. Recommendations

*a) Ecological driving and Fuel tax*

The most promising CO2 emission reduction measures in the transport sector are those aimed at promoting fuel-efficient driving through training and by encouraging the installation of on-board driving assessment systems. This is based on those characteristics that encourage motorists to choose vehicles with lower emissions in countries with very strict emission standards. Therefore, the fuel tax, the standards applicable to vehicles and their components, the modulation of taxes on vehicles and ecological driving are measures used to encourage environment and energy development and aimed at reducing consumption that offer the best prospects for reducing CO2 emissions in the short and medium term. The integration of transport policy and land use planning could, in the long term contain the demand for mobility and the proportion of private vehicles. Ultimately, it will be necessary to resort to much more expensive energy sources, including clean energies such as hydrogen and electricity from renewable sources or fossil fuels with carbon capture and storage, to reduce more CO2 emissions produced by transport. Bringing these technologies to commercial viability will require a significant research and development effort.

*b) Improve the performance of public transport system*

The International reports on the reduction of CO2 emissions mention the measures taken to promote walking and the use of bicycles. Furthermore, an efficiently designed and implemented a public transport system offers a practical mode of travel that reduces the need for private vehicles, and thus reduces CO2 emissions produced per passenger-km traveled. Public transit promotes urban densification and also serves to reduce the distances to be traveled and provides a convenient travel mode that reduces the need for individual vehicles [9].

*c) Traffic management and town planning*

International governments are obliged to create traffic management measures (congestion tolls, vehicle guidance systems, and parking regulations) to reduce CO2 emissions. Indeed, the same is true of the efforts made to integrate regional planning and transport policy, an essential step to control the growth in traffic and CO2 emissions. This omission seems to be attributable to the sharing of responsibilities between the central power and the local communities. It therefore seems justified to assess the role that local authorities can play in reducing CO2 emissions produced by transport, even if energy efficiency must remain one of the major objectives of national policy.

## VIII. Conclusion

Road transportation is the biggest contributor to CO2 emissions, and the second largest source of growth in these emissions in the world. It should be an integral part of any strategy to reduce CO2 emissions. There is no magic solution to the problem of sustainable mobility, but there is a set of tools and measures, which, if deployed in a consistent manner, can help us to reduce CO2 emissions from transport and improve life quality for the various populations. The panel data approach leads to the following conclusion. The restriction of CO2 emissions measured by changes in population density and the massive use of private vehicles. Referring to the empirical study of the 25 countries in the world, the establishment of a green zone and efficient public transport networks can reduce CO2 emissions from the transportation sector. To do this, the world should start planning and investing now in the future to target transformations in urban planning, electrified public transport infrastructure and networks, and the infrastructure necessary for electric vehicles and their location.

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