Short Research Article

A Contribution to More Objective Comparison of Different Countries in Terms of Their Carbon Dioxide Emissions

ABSTRACT

Aims: The paper discusses the problem of objectively comparing different countries in terms of their carbon dioxide emissions, in the light of climate and environmental justice.
Methodology: The analytical method is applied in combination with comparative method. Two traditional and two untraditional indicators are considered. The indicators are applied to a selected group of countries that includes part of the BRICS countries and the G7 countries.
Results: The ratio of the share of carbon dioxide emissions of a country in the global emission and the share of its population in the global population gives approximately the same distribution of countries from the selected group as the ratio of the carbon dioxide emissions of a country and its population. On the other hand, the observation of carbon dioxide emissions togather with carbon dioxide absorption by the forests in relation to the country's population shows a different distribution of the observed countries. The paper also reviews the possibilities of further improvement in the definition of appropriate indicators for a more objective comparison of different countries in terms of their carbon dioxide emissions.
Conclusion: Complex indicators that comprise anthropogenic carbon dioxide emissions, forest absorption capacity and population can contribute to comparison of different countries regarding their carbon dioxide emissions that is more objective from the climate and environmental justice point of view.

Keywords: carbon dioxide emission indicators, environmental justice, climate justice

1. INTRODUCTION

Carbon dioxide emissions are a big global problem, but perhaps even more so, a big problem for individual countries. For underdeveloped and developing countries, the increase in energy consumption per capita is a condition for their industrial, economic and generally social development. Since in those countries a significant part of energy often is based on coal, for them is the fastest and cheapest way to increase energy consumption for the sake of economic and social development linked to an increase in carbon dioxide emissions.

Different patterns of energy use, as well as actual tendency of imposing strict emissions obligations to developing countries, which find it difficult to meet them, or to meet them quickly enough, raise issues of both environmental and climate justice in the form of responsibilities (current vs. historical) and rights (whose needs are most urgent and who decides how much who can emit). These principles actually follow from the concept of energy and climate justice expressed by Newell and Mulvaney, and presented in the Ref. [1].

Regardless of who decides how much carbon dioxide a country can emit, it is necessary previously to determine, that is, to define a more objective comparison of different countries in terms of their carbon dioxide emission. This is exactly what the considerations shown in the rest of this text are devoted to.

2. APPLIED METHOD AND INDICATORS

In the paper is used analytical method combined with comparative method, as well as appropriate indicators that indicate relative carbon dioxide emissions of different countries. The aim is to contribute to objectively comparison countries in terms of their carbon dioxide emissions. The method is applied to a selected group of countries that comprises some BRICS countries and G7 countries.

Total carbon dioxide emissions of a country reduced to its population is the simplest in common use indicator. It implies that every inhabitant of the world has the same opportunities and obligations in terms of carbon dioxide emissions. In analytical form, this indicator is defined by equation (1), as:

$$\mu_{CO2} = M_{CO2} / P_{Ct} \quad (1)$$

Here M_{CO2} and P_{Ct} denote the total annual emission of carbon dioxide and the population of the considered country.

The indicator that represents the ratio of the participation of an individual country in the total global emission of carbon dioxide and the participation of the population of that country in the global population seems very suitable for assessing the contribution of an individual country to the global emission. It is used in the reference [2], as a starting point for considering the connection between possible political changes in the upcoming elections in five countries that are large emitters of carbon dioxide and possible changes in attitudes towards the proclaimed reduction of carbon dioxide emissions in those countries.

The analytical form of the indicator of the ratio of the participation of an individual country in the total global carbon dioxide emission and the participation of the population of that country in the global population is determined by equation (2). For the purpose of this work, we were free to name that indicator with Λ_{MP}.

$$\Lambda_{MP} = \frac{M_{CO2}/M_{GCO2}}{P_{Ct}/P_G} = \mu_{GeCO2}/\pi_{Gp} \tag{2}$$

Here, M_{CO2} and P_{Ct} denote the carbon dioxide emission and the population of the considered country, respectively, while M_{GCO2} and P_G denote the global carbon dioxide emission and the global population. With μ_{GeCO2} and π_{Gp} are denoted the participation of the considered country's emission in the global carbon dioxide emission and the participation of its population in the global population, respectively.

In principle, the entire carbon dioxide emission of a country does not have to be the basis for defining its participation in the global emission. Certain countries may have specific natural conditions that can absorb part of their emissions, which would result in lower level of the carbon dioxide that remains in the atmosphere. In other words, we can assume that every country, in addition to anthropogenic sources of carbon dioxide, also has natural sinks of carbon dioxide, whereby the capacity of these sinks, in principle, varies from country to country. An example of such a sink is the area under forest in the considered country.

2.1 Forests as carbon dioxide sinks

According to data published in the Ref. [3], for the period between 2001 and 2019, the world's forests absorbed approximately twice as much carbon dioxide as they emitted, so we can consider them as a large and powerful "carbon sink". However, not every forest absorbs the same amount of carbon dioxide. Furthermore, the differences between individual forests in terms of the amount of absorbed carbon dioxide per unit area of the land on which the forest is spread can be very large, which according to [3] also depends on how the forests are managed. According to data published by Moseman and others in [4], the most powerful forests in terms of storing capacity are able to store about 100 times more carbon per hectare than the least powerful forests. In this regard, the preservation of existing forests are seen as the priority over the growth of new forests [4].

2.2 Complex indicators

Bearing in mind the previous contemplations, we can consider the carbon dioxide emission indicator for a country, which is determined by the following equation:

$$\mu_{CO2Sf} = \frac{\left(M_{CO2\_Em} - M_{CO2\_Abs\,f}\right)}{P_{Ct}} = \frac{\left(M_{CO2\_Em} - \bar{q}_{f\,CO2}\cdot S_f\right)}{P_{Ct}} \tag{3}$$

In the above equation M_{CO2_Em} (in t/a) denotes anthropogenic carbon dioxide emissions per annum, M_{CO2_Abs} (in t/a) denotes amount of anthropogenic carbon dioxide absorbed by forests per annum. With $\bar{q}_{CO2}$ (in t/km^{2}a) is denoted the average value of absorption capacity of the total forest's area S_f (in km^2) in the considered country. For a country with a sufficiently large area under forest and a relatively moderate emission of anthropogenic carbon dioxide, the numerical value of the indicator, which is defined in this way, can be negative. Such a country is a net absorber of carbon dioxide, in contrast to countries with a positive numerical value of the carbon dioxide emission indicator that are net emitters of carbon dioxide.

The average value of absorption capacity of all forests $\bar{q}_{CO2}$ (in t/km^{2}a) in the observed country is determined by the expression:

$$\bar{q}_{f\,CO2} = \frac{1}{S_f}\cdot\sum_{i=1}^{n} q_{fCO2i}\cdot s_{f\,i} \tag{4}$$

With q_{fCO2i} (in t/km^{2}a) and s_{fi} (in km^2) are denoted absorption capacity and the area of the *i*-th part of the total forest area.

Determining the numerical value of the average forest absorption capacity for each individual country is a special and very complex task. To solve it, it is necessary to combine field measurements and satellite observations. On the other hand, it can significantly contribute to the objective assessment of the emission of each country in relation to the global emission.

The next thing we can do to increase the objectivity of the assessment of each country's contribution to global emissions is to include the absorption capacity of the algae found in the surface waters. In this sense, we can assume that surface waters on land will also absorb part of the emitted carbon dioxide. In that sense can be defined the general carbon dioxide emission indicator by the following equation:

$$\mu_{CO2Sf\,S_w} = \frac{\left(M_{CO2\_Em} - M_{CO2\_Abs\,f} - M_{CO2\_Abs\,w}\right)}{P_{Ct}} = \frac{\left(M_{CO2\_Em} - \bar{q}_{fCO2}\cdot S_f - \bar{q}_{wCO2}\cdot S_w\right)}{P_{Ct}} \quad (5)$$

Here M_{CO2_Absf} and M_{CO2_Absw} (in t/a) denote the annual amount of anthropogenic carbon dioxide absorbed by forests and aquatic flora for one year, respectively. With $\bar{q}_{fCO2}$ (in t/km^{2}a) and $\bar{q}_{wCO2}$ (in t/km^{2}a) are denoted the average amount of absorption capacity of all forests and of all hydro flora, respectively, while S_f and S_w denote the total area of the forest and of the surface water in the observed country, respectively.

The average value of absorption capacity of all forests $\bar{q}_{fCO2}$ (in t/km^{2}a) is determined by equation (4), while the average amount of absorption capacity of all hydro flora $\bar{q}_{wCO2}$ in (in t/km^{2}a) in the observed country is determined by the expression:

$$\bar{q}_{wCO2} = \frac{1}{S_w}\cdot\sum_{j=1}^{m} q_{wCO2i}\cdot s_{w\,j} \quad (6)$$

With q_{wCO2j} (in t/km^{2}a) is denoted the absorption capacity of the *j*-th part of the water surface, respectively, while s_{wj} (in km^2) denote the area of the *j*-th part of the total water surface area.

The average amount of absorption capacity of the hydro flora depends on the purity of the water and its temperature. Note that equations (1), (3) and (5) have the same dimension: tons of carbon dioxide per capita, per annum, while equation (2) is dimensionless.

3. RESULTS AND DISCUSSION

The calculated numerical values of the Λ_{MP} indicator for the selected group of countries, based on data from the references [5] and [6], are presented in Fig. 1. It is actually the same indicator that was used in the Ref. [2]. Canada USA and Russia appear as the greatest carbon dioxide emitters. The same order of the selected countries regarding indicated emission level can be also obtained with the equation (1), since the ratio of Eq. (2) and (1) is a constant number, equal for all countries.

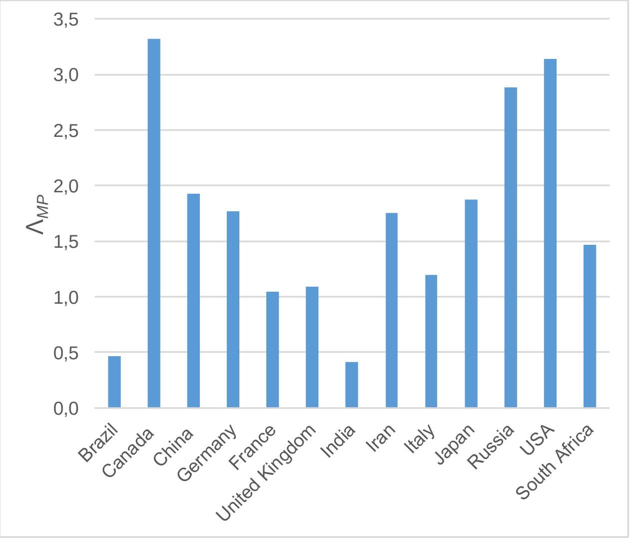

Figure 1. Λ_{MP} indicator for carbon dioxide emissions of a selected group of countries. For the calculation data from Refs. [5 and 6] are used

The concept of the equation (2), enable us to display the considered countries in the coordinate system: "Country share in global population - country share in global carbon dioxide emissions", which is presented in Fig. 2. We see that equation (2) actually defines the tangent of the angle that the state position vector from Figure 2 coincides with the axis: "population share in the world population". This kind of display further enables indicating the countries that let us say, "transfer" a part of their emissions to other countries, that is, to the "global level". Namely, it follows that the country for which $\Lambda_{MP} > 1$ will have a greater share in global carbon dioxide emissions than its share in the global population. For a country with $\Lambda_{MP} < 1$, it follows that its share in global carbon dioxide emissions will be less than its share in the global population. In other words, all countries above the dotted line in Fig. 2 have $\Lambda_{MP} > 1$ that can be interpreted as the countries "spilling" part of their carbon dioxide emissions to other countries. On the other hand, all countries below that line have $\Lambda_{MP} < 1$, which practically means that they "receive" part of the carbon dioxide emissions from other countries. Finally, a country with the same numerical values of participation in global emissions and in the global population, i.e. with $\Lambda_{MP} = 1$, has zero "spillover" of its emissions to other countries and zero "reception" of emissions from other countries. The presented division into countries that pour part of their emissions onto other countries and those that receive emissions from other countries, as well as neutral countries in this regard seems very usable and very practical. However, we can put a question: is this approach sufficiently objective?

The contribution of each of the countries from the selected group to the global carbon dioxide emission, calculated using equation (3), is presented in Fig. 3. The calculations are made with the numerical value $\overline{q}_{fCO2}$ = 190 t/km^{2}a, which approximately corresponds to the average absorption capacity of forests at the global level, calculated according to data published in the Refs. [5 and 7].

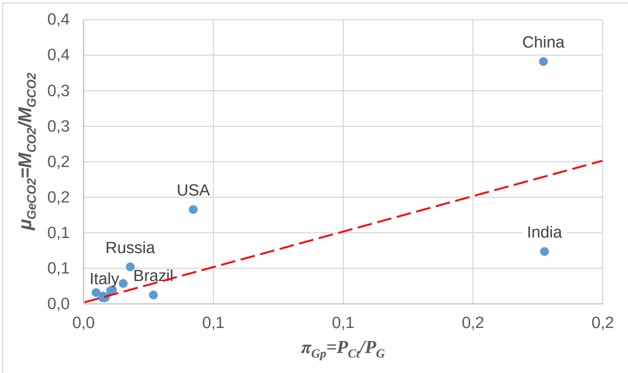

Figure 2. Considered countries in the diagram: "Share in global population - share in global carbon dioxide emissions", based on data from Refs. [5 and 6]

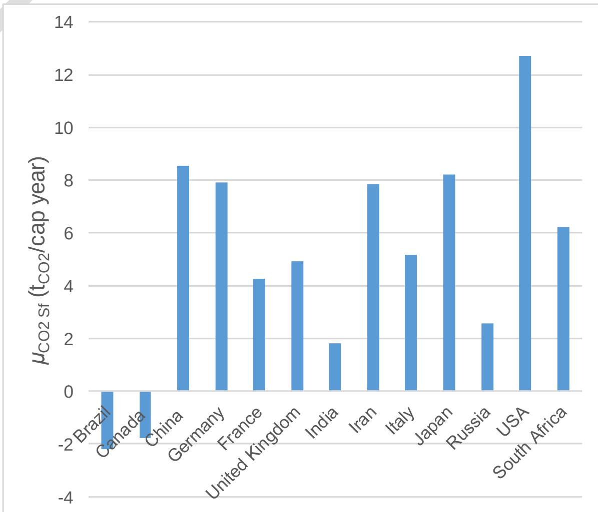

Figure 3. Carbon dioxide emission indicator for a selected group of countries, based on data from the Refs. [5, 6 and 7]

From Figure 3, we see the existence of two groups of countries: 1) net emitters of carbon dioxide, for which $\mu_{CO2Sf} > 0$ and which can be divided into large, medium and small net emitters, and 2) net absorbers of carbon dioxide, for which $\mu_{CO2Sf} < 0$. Introduction of the available forest area in the calculation of the contribution of an individual country to the total global emission of anthropogenic carbon dioxide significantly changes the mutual relationship of the countries from the selected group. Of the countries with the largest emitters from Fig. 1, namely: Canada, Russia and the USA, according to this criterion the USA is still the largest net emitter, Russia together with India is in the group of the smallest net emitters, while Canada, together with Brazil, enters the group of carbon dioxide net absorbers. This calculation is made under the assumption that all countries have forests with the same absorption capacity, approximately equal to the average carbon dioxide absorption capacity of all forests in the world, and that the countries differ only in the area covered by their forests, which, of course, represents a certain approximation.

Determining the numerical value of the forest’s absorption capacity for each individual country is a special and very complex task. On the other hand, it can significantly contribute to the objectivity of the emission’s assessment for each considered country. Therefore, these analyses are recommended to be subject of the possible future research.

Inclusion algae’s absorption capacity in calculation procedure for determining distribution of countries regarding indicated carbon dioxide emission level is connected with estimation numerical value of hydro flora’s absorption capacity. This estimation is very complex problem. For the purpose of exemplified calculations the value of 75 t/km^{2}a is used. Obtained order of the considered countries is almost the same as those in Fig. 3, with only difference that in this case Canada is greater net absorber of carbon dioxide than Brazil.

The oceans and seas are huge carbon dioxide reservoir, whereby predominant quantity lays in the ocean's deep parts [9]. However, the surface of seas and oceans are considered as a common good that belongs to all countries and therefore is not included into definition of the general carbon dioxide emission indicator.

4. CONCLUSION

From the point of view of ecological justice and the protection of existing forests, but also from the point of view of energy justice, it is very important that underdeveloped and developing countries are the owners of the land and forests on their territory. By protecting and domestically managing their forests, those countries can provide, for them, the most favorable energy from solid fossil fuels without increasing cross-border carbon dioxide emissions. This conclusion is in line with the standpoint of Moseman and others that the enforcement of ownership rights of indigenous peoples and local communities over their forests is a proven strategy for protecting existing forests and increasing the total amount of carbon stored in them [4].

The purpose of indicating the contribution of carbon dioxide emissions from individual countries to the global emission is to indicate which countries can be considered as ones that transfer part of their emissions to the global level, and which countries can be considered as emitters only within their borders. In other words, which countries are the net emitters of anthropogenic carbon dioxide and which countries are the net absorbers. This is a very sensitive question and therefore the answer to it must be objective, scientifically based and socially acceptable. This paper provides a contribution to the analysis of the problem of objective comparison of different countries in terms of their carbon dioxide emissions.

The approach that considers difference between emitted anthropogenic carbon dioxide and absorbed by forests carbon dioxide contribute to the objectivity of comparing carbon dioxide emissions among different countries.

Another important field for application of environmental indicators is within the scope of energy transition and post transition analysis. Concept of energy transition and post transition as presented in Ref. [10] is limited on energy system and on the change of its structure as well. However, it would be more appropriate to extend the analysis and to comprise the change in environmental system's structure along the power system's transition trajectory.

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