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Indicating Contribution of a Country to Global CO2 Emission and Environmental Justice

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Abstract: 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. Two traditional and three nontraditional indicators are included. The indicators were applied to a selected group of thirteen countries that includes part of the BRICS countries and the G7 countries. 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 makes a basis for comparison different countries. For defining just relation among the countries regarding carbon dioxide emissions, it is necessary to identify the sinks of carbon dioxide and to include them into the definitions of the emission's indicators. A possible approach in that direction is presented in the paper. Further improvements in the definition of appropriate indicators for an objective comparison of different countries in terms of their carbon dioxide emissions are presented and exemplified.

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

1. Introduction

Emissions of carbon dioxide in certain countries, that is, across their borders, are increasingly the subject of heated discussions at the international level. On the one hand, there are the wishes of developed countries from the G7 group to abolish coal subsidies [1]. On the other hand, underdeveloped and developing countries have a legitimate desire to increase their level of development as soon as possible and to reduce their lag behind developed countries. For them, an increase in the consumption of primary energy per capita is necessary for their development. The fastest and for them the simplest way to increase the consumption of primary energy per capita is directly related to the increase in the consumption of fossil fuels and, ultimately, to the increase their carbon dioxide emissions [2]. In this context, important questions of energy, environmental and climate justice have to be raised.

The tendency to impose strict carbon emissions obligations on developing countries with significantly different energy use patterns, which find it difficult to meet these obligations, or to meet them quickly enough, raises issues of both environmental and climate justice in the form of accountability (current vs. historical) and rights (whose needs are most urgent and who decides who can emit how much carbon dioxide) [3]. The principles of environmental justice set in this way actually follow from the concept of energy justice that Neville and Mulvaney (Newell and Mulvaney) presented in the literature [4].

Regardless of defining how much carbon dioxide a country can emit and who decides about it, it is necessary first to define an objective assessment of the contribution of each individual country to the total global emission.

2. Basic indicators

The simplest indicator of a country's carbon dioxide emissions is the ratio of its annual emissions to its population, expressed in tons per capita. It implies that every inhabitant of the world has the same rights and the same obligations regarding carbon dioxide emissions. In analytical form, this indicator is defined by equation (1), as:

$$\mu_{CO2} = \frac{M_{CO2\_Em}}{P_{Ct}} \tag{1}$$

Here M_{CO2_Em} and P_{Ct} denote the total annual emission of carbon dioxide and the number of inhabitants of the observed country. A comparative view of carbon dioxide emissions per capita for some countries from the BRICS group and for the countries of the G7 group, according to data provided in the literature [5], is presented in Fig. 1.

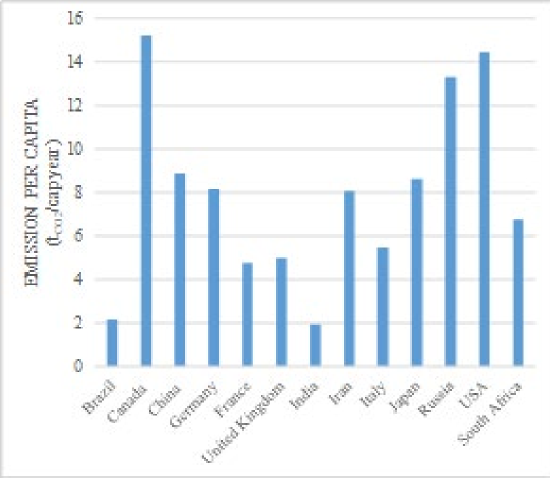

Figure 1. Carbon dioxide emissions per capita for selected group of countries, according to data from [5]

A slightly more complex indicator 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. The indicator formulated in this way seems very suitable for assessing the contribution of an individual country to global emissions. It was, for example, used in the literature [6], 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. In analytical form, this indicator is determined by equation (2).

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

M_{CO2} and P_{Ct} denote the carbon dioxide emission and the number of inhabitants of the observed country, respectively, while M_{GCO2} and P_G denote the total global carbon dioxide emission and the global population. μ_{GeCO2} and π_{Gp} indicate the participation of the observed country's emission in the global carbon dioxide emission and the participation of its population in the global population, respectively. The mutual distribution of the selected countries according to this indicator must be the same as in Figure 1, since the ratio of these two indicators is:

$$\frac{\Lambda_{MP}}{\mu_{CO2}} = \frac{P_G}{M_{GCO2}} = K_G \tag{3}$$

Where the K_G represents the global characteristic.

Equation (2) has some other important advantages. For example, we can form a two-dimensional coordinate system: "Country share in global population" – "country share in global carbon dioxide emissions", which is graphically represented in Fig. 2, according to [3]. We see that equation (2), defines the tangent of the angle which the position vector of each country from Fig. 2 overlaps with the axis: "population share in the world population". This kind of presentation further enables us to numerically indicate the countries that "transfer" a part of their emissions to other countries, that is, to the "global level". A country for which $\Lambda_{MP} > 1$ will have a greater share in global carbon dioxide emissions than its share in 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 red dotted line in Fig. 2 will have $\Lambda_{MP} > 1$, which we can interpret as those countries "spilling" part of their carbon dioxide emissions to other countries. On the other hand, all countries below that line will have $\Lambda_{MP} < 1$, which practically means that they will "receive" part of the carbon dioxide emissions from other countries. The described approach also leads us to the conclusion that 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 principle of dividing all countries in the world into countries that transfer their emissions to other countries and those that receive emissions from other countries, as well as neutral countries in this respect, looks very usable and very practical. However, we can put the question: is this approach in line with environmental and climate justice?

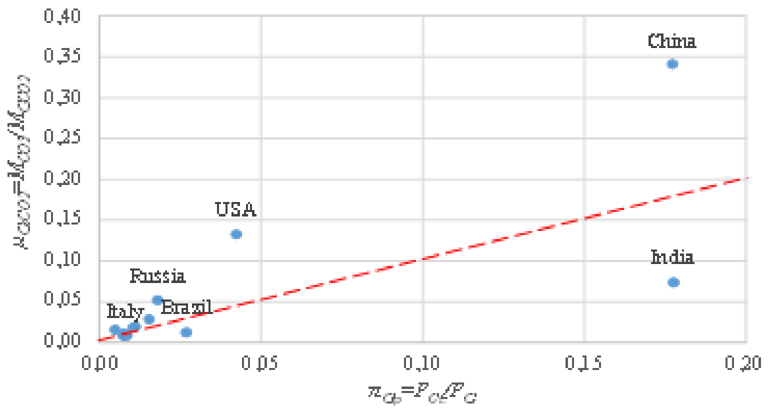

Figure 2. Considered countries in the diagram: "Share in global population - share in global carbon dioxide emissions", based on data from Refs. [5, 7]

3. A contribution to development of complex indicators

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 enable the absorption of part of their emissions and, therefore, a smaller contribution to global emissions. 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 a forest expanse in the country under consideration. In principle, for comparing the contribution of one country to the global emission, it is important to comprise and the effect of the carbon sinks in it.

3.1. Forests as carbon dioxide sinks

According to data published in the literature [8], in the period between 2001 and 2019, all 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". Long spanning research the results of which are published in [9], point out that the global forest carbon sink is equivalent to almost half of fossil-fuel emissions. However, not every forest absorbs the same amount of carbon dioxide. 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 [8] essentially depends on how they are managed. According to data published by Moseman and others in [10], the most powerful forests in terms of absorptive capacity are able to absorb up to 100 times more carbon per hectare than the least powerful forests. In this regard, the preservation of existing forests has priority over the growth of new forests [10].

3.2. Complex indicators

The simplest way to introduce areas under forests into the procedure for estimating effective carbon dioxide emissions would be to reduce the emission of anthropogenic carbon dioxide of a country to the product of its population and its area under forests expressed in square kilometers. Thus, we arrive at the definition of "Relative carbon dioxide emissions" (in relation to population and area under forest) of a country ξ_{SO2Sf}, which is numerically determined by the following equation:

$$\xi_{CO2Sf} = \frac{M_{CO2}}{P_{Ct} \cdot S_f} = \frac{M_{CO2}}{P_{Ct} \cdot \sigma_{Sf} \cdot S_{uk}} \tag{4}$$

Here, S_f and S_{uk} denote the area occupied by forest in the considered country and the total area of that country, respectively. With σ_{Sf}, the afforestation of the country is indicated as the ratio of the area under forest to the total area of the country.

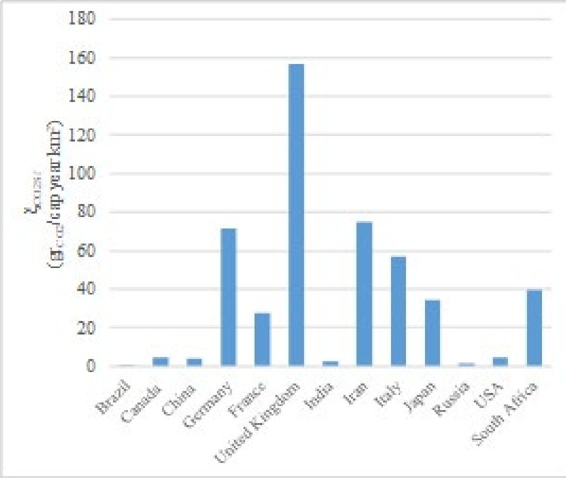

Figure 3. Relative carbon dioxide emissions for selected group of countries, according to data from [5, 7] and [11]

The contribution of each of the countries from the selected group to the global emission of carbon dioxide, calculated using equation (4), is shown in Fig. 3. This calculation is made under the assumption that all countries have forests with the same ability to absorb carbon dioxide and that they differ only in the area covered by their forests, which does not correspond to reality. We can see that the order of the considered countries is somewhat different compared to the order in Fig. 1, that is, when using equation (1). The dimension of the relative carbon dioxide emissions indicator is tons of carbon dioxide per inhabitant and square kilometer of the considered country's surface. However, even this indicator does not provide an answer to the question of how much a specific country "spills over" part of its anthropogenic carbon dioxide emissions to other countries, that is, to the global level.

When defining the fores'ts impact on the spillover part of anthropogenic carbon dioxide to other countries, it is necessary to take into account the absorptive capacity of the forest in the specific, or considered, country. Such considerations lead us to the specifically formulated indicator named "Carbon dioxide emission indicator" of a country. This indicator is defined as the ratio of the difference between emitted and absorbed carbon dioxide and the number of inhabitants of the observed country, or in analytical form with the following equation:

$$\mu_{CO2Sf} = \frac{\left(M_{CO2\_Em} - M_{CO2\_Abs\,f}\right)}{P_{Ct}} = \frac{M_{CO2\_Em}}{P_{Ct}} \cdot \left(1 - \frac{M_{CO2\_Abs\,f}}{M_{CO2\_Em}}\right) = \mu_{CO2} \cdot (1 - \Theta) \tag{5}$$

Here M_{CO2_Em} (in t/a[1]) indicates the amount of anthropogenic carbon dioxide emissions for one year in the observed country, M_{CO2_Abs} (in t/a) indicates the annual amount of anthropogenic carbon dioxide absorbed by forests in the same country for one year, P_{St} is the number of inhabitants of that country, μ_{SO2} is determined by equation (1), while Θ represents the ratio of annual amounts of absorbed and emitted carbon dioxide.

If we assume the general case that certain parts of the total forest area of a country have different absorption capacities of carbon dioxide, then the ratio of annual amounts of absorbed and emitted carbon dioxide Θ will be determined by the following equation:

$$\Theta = \frac{M_{CO2\_Abs\,f}}{M_{CO2\_Em}} = \frac{\sum_{i=1}^{n} q_{fCO2i} \cdot s_{fi}}{M_{CO2\_Em}} = \frac{\bar{q}_{fCO2} \cdot S_f}{M_{CO2\_Em}} \tag{6}$$

Here q_{CO2i} (in t/km^{2}a) and s_{fi} (in km^2) denote the average amount of absorption power and the area of the i-th part of the total forest area S_f of the observed country, respectively. For a country with a sufficiently large area under forest and a relatively small emission of anthropogenic carbon dioxide, it can be $\Theta > 1$, which has, as a consequence, a negative numerical value of the indicator of carbon dioxide emission defined by equation (5). Such a country is a net absorber of carbon dioxide, in contrast to countries with a positive numerical value of

[1] t/a – tons per annum

this indicator, which are net emitters of carbon dioxide due to $\Theta < 1$. A country for which $\Theta = 1$ will be emission neutral, i.e. it will neither spillover nor receive carbon dioxide.

Determining the numerical value of the average forest absorption capacity factor for each individual country $\bar{q}_{fCO2}$ (in t/km^{2}a) represents a special and very complex problem. To solve it, it is necessary to combine field measurements and satellite images. On the other hand, it can significantly contribute to the objective assessment of each country's emission in relation to the global emission and to the objective assessment of the spillover of anthropogenic carbon dioxide emissions to other countries, that is, to the global level. In final level, it contributes to the environmental justice in comparison carbon dioxide emissions among different countries.

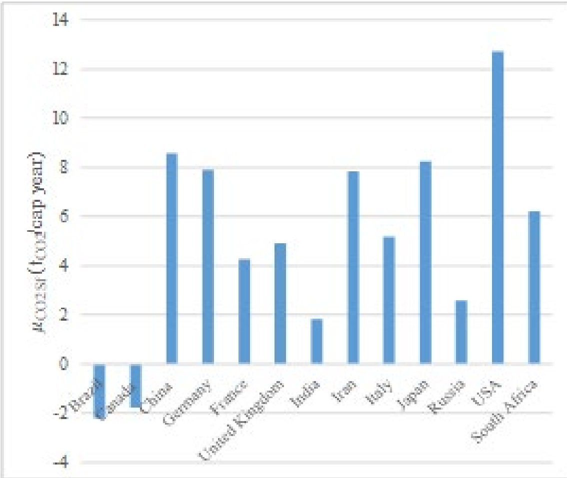

Figure 4. Carbon dioxide emission indicator for selected group of countries, according to data from [5, 7, 11]

The contribution of each country from the selected group to global carbon dioxide emissions, calculated using equation (5), is shown in Fig. 4, according to [3]. The calculations were made with the numerical value $\bar{q}_{fCO2}$=190, which approximately corresponds to the average absorption capacity of forests at the global level, calculated according to the data published in the literature [8 and 11]. From Fig. 4, two groups of countries are clearly visible: 1) net emitters of carbon dioxide, for which $\mu_{CO2Sf} > 0$, i.e. $\Theta < 1$, and which can be large, medium and small net emitters, and 2) net absorbers of carbon dioxide for which is $\mu_{CO2Sf} < 0$, i.e. $\Theta > 1$. The introduction of the available forest area in the calculation of the contribution of individual countries to the total global emission of carbon dioxide significantly changes the mutual relationship of the countries from the selected group. Of the largest emitter countries from Figure 1, namely: Canada, Russia and the USA, according to this criterion the USA is still the largest emitter, Russia, together with India, is in the group of the smallest net emitters, while Canada, together with Brazil, is in the group of net absorbers carbon dioxide. 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 countries differ only in the area covered by their forests, which, of course, represents a significant approximation.

The next thing that can be done toward improving the assessment of each country's contribution to global emissions is to include the absorptive capacity of the flora found in the surface waters of each country. In this sense, in [3] is assumed that surface waters on land will also absorb part of the emitted carbon dioxide. This thinking leads to the concept of "Total carbon dioxide emission indicator", which is defined by the following equation:

$$\mu_{CO2Sf\,S_w} = \frac{\left(M_{CO2\_Em} - M_{CO2\_Abs\,f} - M_{CO2\_Abs\,w}\right)}{P_{Ct}} = \mu_{CO2}\cdot\left(1-\Theta-\Omega\right) \qquad (7)$$

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, μ_{SO2} is determined by equation (1), while Ω represents the ratio of water flora absorbed annually the amount of carbon dioxide and emitted carbon dioxide in the observed country. In the general case when certain parts of the total water surface of a country have different carbon dioxide absorption capacities, the ratio of annual amounts of absorbed and emitted carbon dioxide Ω will be determined by the following equation:

$$\Omega = \frac{M_{CO2\_Absw}}{M_{CO2\_Em}} = \frac{\sum_{j=1}^{m} q_{wCO2j} \cdot s_{wj}}{M_{CO2\_Em}} = \frac{\overline{q}_{wCO2} \cdot S_w}{M_{CO2\_Em}} \tag{8}$$

With q_{wCO2j} (in t/km^{2}a) is denoted the mean amount of absorption power of the j-th part of the water surface, with s_{wj} (in km^2) the surface of the j-th part of the total water surface, and with S_w the total surface under water in the observed country, respectively.

The average amount of the hydroflora's absorption power depends on the purity of the water and its temperature. For the purposes of the calculation example, in [3] is assumed numerical value of $\overline{q}_{wCO2} = 75$. The calculations performed in [3] point out almost the same distribution of considered countries as in Figure 4, with Canada now being the largest carbon dioxide absorber. It should be kept in mind that these calculations, as well as the calculations for the Fig. 4 were made with supposed numerical values of the mean absorptive capacity of forests and of surfaces under water.

Note also that equations (1), (5) and (7) have the same dimension: ton of carbon dioxide per inhabitant per year, equation (4) has the dimension: ton of carbon dioxide per inhabitant per year and square kilometer, while equation (2) is dimensionless.

In previous analyses, only continental surface waters were taken into account, but not the surface of seas and oceans, given that we consider these other surfaces as a common good that belongs to all countries.

4. Just energy transition and climate justice

Inclusion the absorptive capacity of forests in the evaluation of the carbon dioxide's effective emission represents an important issue of ecological and climate justice, but also an important issue of a just energy transition. Considering forests as sinks of carbon dioxide follows from the United Nations Framework Convention on Climate Change [12]. Since forests as carbon sinks reduce the effects of anthropogenic carbon dioxide emissions, for each specific country, it is necessary to take into account the area under forest, the maintenance of forests and the nature of forests in order to accurately define the absorption coefficient of those forests.

In the draft of the Strategy for development of energetics in Republic of Serbia [13], the reduction of the share of coal-fired power plants (lignite) in the total production of electricity is foreseen to about 50% in 2040, at the expense of increasing production from i-RES, for the purpose of reducing carbon dioxide emissions. This implies a corresponding reduction of employees in coal mines and thermal power plants, but also a reduction of the GDP in the areas of coal mines and thermal power plants. All this for the sake of reducing carbon dioxide emissions in Serbia.

The rough analysis carried out for the purpose of this paper shows that the current area covered by forests in Serbia, with the average absorption capacity of the world's forests (190 t/km^2), in terms of reducing the effective emission of carbon dioxide, corresponds to the reduction of the possible production of thermal power plants Nikola Tesla A and B in 2019 [14], by 25%. This figure is already of great importance for the extension of coal and electricity production activities, because the eventual reduction in production would be only about half of the predicted figure from the Strategy for development of energetics in Republic of Serbia [13]. Of course, the figure of 190 t/km^2 is based on the estimated value of the absorption capacity of Serbian forests. This assumption must be proven by appropriate empirical research. However, it is not unreasonable to assume that these studies could also show even higher absorptive capacity of Serbian forests taken together with flora in the water surfaces, as well as with the agricultural flora.

Precise determination of the capacity of Serbian forests to absorb carbon dioxide is possible only within a complex scientific research project. That project should have two parts. In the first part, it should be realized the necessary recordings on the ground and, if the need dictates and the possibilities permit, satellite recordings. On the basis of these studies, the sectors of areas under the forest with similar carbon dioxide absorption capabilities should be determined, as well as the average absorption capabilities of each of the defined sectors.

In the second part of the scientific research project, it is necessary to create a specific mathematical model for calculating the possible and the most likely absorption of carbon dioxide emitted from various industrial emitters in Serbia. Here, in addition to the emission intensity of individual emitters and the absorption capacity of individual sectors of the forest area, their spatial distribution and movement of air masses with carbon dioxide should be taken into account. One of the results of such a project would be software for calculating carbon dioxide absorption in Serbian forests in real time.

If, through appropriate research can be achieved, on one hand the more precisely determination of the absorptive capacity of Serbian forests, as well as the possible achievement that could be obtained by better forest management, and on the other hand of possible increase in the area under forests in Serbia by 2040, that is, by 2050, the prospects for further production of electricity from coal in Serbia and, on that basis, the realization of a GDP are not at all without foundation. On the other hand, in order to install solar power plants and wind power plants in Serbia, the most probably even cutting of forests will be necessary.

5. Conclusions

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 view 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 [10].

Indicating the share of carbon dioxide emissions from individual countries in the global emission aims to indicate which countries transfer part of their emissions to the global level, and which countries have emissions only within their borders. This is a very sensitive question and therefore the answer to it must be objective and scientifically based. This paper provides a contribution to the analysis of the problem of objective comparison of different countries in terms of their carbon dioxide emissions. Observing a country's carbon dioxide emissions in relation to its population and its area under forests could contribute to environmental and climate justice on the global level. In this light, we can look at the discussed possibilities of further improving the objectivity of comparing carbon dioxide emissions between different countries.

Finally, it is important to mention that above defined environmental indicators can be applied within the scope of expanding, in the literature [15] already presented, analysis of energy systems' energy transition and post-transition and in that respect for selection of the most competitive transition trajectory. Environmental indicators enable joint analysis of an energy system and the environment in the scope of the energy transition. Development of forestation can lead to better achievements in main energy transition goals: the country's sustainable development, as well as a carbon-free economy.

Disclaimer (Artificial intelligence)

Author hereby declares that no generative AI technologies such as large language models (*ChatGPT*, *COPILOT*, etc.) and text to image generators have been used during writing or editing this manuscript.

Competing interests

Author hereby declares that there have been no conflicting financial interests or personal relationships that could influence the creation of the presented work.

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