Revista de Estudos Internacionais (REI), ISSN 2236-4811, Vol. 10 (1), 2019

THE CLIMATE CHANGE REGIME AND THE NATIONAL CARBON FOOTPRINT: A QUALITATIVE COMPARATIVE ANALYSIS OF THE CAUSES OF A HIGH CARBON FOOTPRINT

O REGIME DE MUDANÇAS CLIMÁTICAS E A PEGADA DE CARBONO NACIONAL: UMA ANÁLISE QUALITATIVA COMPARADA DAS CAUSAS DE UMA ALTA PEGADA DE CARBONO

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Abstract: The purpose of this paper is to identify which variables condition countries to have a high carbon footprint. To this end, we will employ Qualitative Comparative Analysis (QCA), a technical approach used not only deductively to test hypotheses, but also inductively, bringing new insights and further theoretical development for further research. Thus, this paper consists in an exploratory research about what causes countries to have a high carbon footprint, by inserting political variables in the analysis. In the data analysis, results have shown that, for countries to have a high carbon footprint, they need to have a large per capita GDP or a high performance in the Education HDI, or both. In the sufficiency analysis, two different configurations were sufficient to produce the result: the first was a combination of a high per capita GDP, high internal politics openness and high performance in education; the second combination involved the signature of a few environmental agreements, low internal political openness and a high per capita GDP.

Key-words: Carbon Footprint. Environmental Policy. Climate Regime. Environmental Agreements. QCA.

Resumo: O objetivo deste artigo reside em identificar quais variáveis condicionam os países a terem uma alta pegada de carbono. Para esse fim, utiliza-se da Análise Comparativa Qualitativa (QCA), uma abordagem técnica usada não apenas dedutivamente para testar hipóteses, mas também de forma indutiva, trazendo novos insights e desenvolvimento teórico adicional para futuras pesquisas. Desta forma, este trabalho consiste em uma pesquisa exploratória sobre o que faz com que os países tenham uma alta pegada de carbono, inserindo variáveis políticas na análise. Depois da análise dos dados, os resultados mostraram que, para os países terem uma pegada de carbono elevada, eles precisam ter um PIB grande per capita ou um alto desempenho no IDH Educação ou ambos. Na análise de suficiência, duas configurações diferentes foram suficientes para produzir o resultado: a primeira foi uma combinação de alto PIB per capita, alta abertura política interna e alta performance em educação; a segunda combinação envolveu a assinatura de alguns acordos ambientais, baixa abertura política interna e alto PIB per capita.

Palavras-chave: Pegada de Carbono. Política Ambiental. Regime Climático. Acordos Ambientais. QCA.

Recebido: 06/03/2019
Aprovado: 07/03/2019

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Introduction

Issues related to global warming are becoming increasingly relevant for the academic debates in International Relations. Although the questions related to CO2 Emissions are multifaceted, studies in International Politics play a fundamental role in the discussion of the diagnosis and solutions for the crises. While Natural Sciences provide the necessary apparatus for the analyses, research involving decision-making aspects may contribute more directly to clarify the current political impasses.

The proposal of this article is to present an exploratory research about what causes countries to have a high carbon footprint by inserting political variables in the analysis, since most of the specialized literature about the theme focuses on economic variables (HALICIOGLU (2009); PAO and TSAI, 2010; SOYTAS, SARI and EWING, 2007; HALICIOGLU, 2009). Thus, the research problem includes political and economic variables that imply a high carbon footprint. Besides the per capita GDP, we introduced in the research issues related to the degree of internal politics openness and the number of environmental agreements signed by the countries to establish a connection with the literature in Political Science and International Relations. We have also incorporated a variable related to the educational development of countries.

Given the exploratory character of the analysis, the goal of this paper is to generate hypotheses to foster the debate further than the economical discussions. To this end, we will employ Qualitative Comparative Analysis (QCA), a technical approach used not only deductively to test hypotheses, but also inductively, bringing new insights and further theoretical development for further research. Differently from statistical analysis, QCA aims to find necessary and sufficient conditions for yielding the result, since the method is an application of Formal Logic to Social Sciences.

The main advantage of using a configurational approach is the possibility to verify how the different condition may be combined to cause the phenomenon. Furthermore, another important difference in QCA with respect to statistical methods is the possibility of having different ways to reach the same result. For instance, different configurations may be sufficient to cause a high carbon footprint even though they are not related amongst themselves. Thus, we argue that the use of QCA may bring a new perspective of the problem for the literature.

In the first part of the article, we will present a literature review of the international environmental regimes, with a special focus on climate regime and issues related to carbon footprint. Secondly, we will describe the methodological aspects of the research. Lastly, we will present the results found. In the data analysis, results have shown that, for countries to have a high carbon footprint, they need to have a large per capita GDP or a high performance in the Education

HDI, or both. In the sufficiency analysis, two different configurations were sufficient to produce the result: the first was a combination of a high per capita GDP, high internal politics openness and high performance in education; the second combination involved the signature of a few environmental agreements, low internal political openness and a high per capita GDP.

1. The Emergence of Environmental Debates in International Affairs and the International Climate Change Regime

The 1970's and 1980's were a significative period for the emergence of discussions about the environment in International Relations. In this light, "the environment became the object of public policies, while the number juridical measures and institution grow both in the national as well as in the international levels" (LE PRESTE, 2000, p. 166). To Chasek, Downie and Brown (2014), the appearance of the environmental politics in the international level can be understood in the light of the birth of environmental movements in the industrialized countries and of the global environmental challenges. These dilemmas have since been seen as sources of deep threats to the welfare of mankind – such as the limits of the ozone layer, global climate changes and the loss of biodiversity – thus raising environmental questions to a new *status* in international politics (CHASEK; DOWNIE; BROWN, 2014).

In this conjuncture, while analyzing the literature on the environment, Jakobsen (1999) pinpoints two groups – on the one hand, the existence of theoreticians of International Relations that concentrate their studies on a state centric perspective and in the regime theories; on the other hand, the green theory academics that consider a variety of actors capable of being agents on the international environmental politics. Zürn (2018), on his turn, has identified five themes on the studies on international environmental politics – the need for a holistic perspective, agenda configuration, regime formation, regime efficacy and the action of transnational networks. To the author, the holistic perspective and the agenda configuration have not reached a satisfactory development in their field of study. On the other hand, regime formation, their efficacy and the dealing with transnational networks have shown a greater explanatory power (ZÜRN, 2018).

Given the reaction to the mainstream formal organizational studies, the appearance of regime theory, in the 1970's, was one of the most significant advances amongst international affairs researchers and analysts (BREITMEIER et al., 2006). In this sense, Breitmeier, Young and Zürn (2006) argue that international regimes are social institutions created in an anarchic scenario to answer specific global governance problems.

During the 1990's, the field started to gain visibility through the growing number of books, magazines, university courses, conferences and seminars, thus demonstrating the academic discipline success (O'NEILL, 2009). In this light, studies about global environmental politics

started do develop and test hypotheses about the nature and efficacy of cooperation processes, besides adopting a dialogue interface with other social sciences, as well as the adoption of various methodologies (O'NEILL, 2009). A relevant maturity indicator of a new study field relates to the creation of new journal dedicated to the publication of international environmental policies as pointed by Cass (2014). Although the main international affairs journals had articles on global environmental policy during the previous two decades, it was only from the 1990's onwards that the *insights* on global environmental policy stated to gain greater visibility (CASS, 2014).

In the political field, due to the conflict between environmental qualities and the need for development, the United Nations General Assembly commissioned a report to the Environmental and Development World Commission, presided by Gro Harlem Brundtland and Mansour Khalid (MOTA et al., 2008). Thus, in 1987, the report entitled *Our Common Future: from one Earth to one World* spread the concept of sustainable development and thus it became a central term, present in the international environmental policies (MOTA et al., 2008).

Due to the need of widening the discussions about the theme, in 1988, the United Nations Environmental Program (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) that took the goal of deepening the scientific knowledge, so as to foster political implications about climate change processes (DYER, 2014). The recognition of the environmental problems drove the Rio 92 conference to adopt the United Nations Framework-Convention about Climate Change (UNFCCC), instrument representing a significant step towards mitigating the elevation of Greenhouse Effects Gases (GEG) as a way to minimize the effects caused by climate changes (MOREIRA & GIOMETTI, 2008).

Emphasizing the need to promote practices based on sustainable development, during COP 3, in 1997, UNFCCC, through the Kyoto Protocol, established the Clean Development Mechanism (CDM) – which enables developed countries to fund environmental projects in developing countries given the offsetting entries of the GEG emission quotas (BOYD et al., 2008). The CDM institutionalization was one of the main advances of mitigation policies facing the climate changes processes. According to Boyd, Corbera and Estrada (2008), the Kyoto Protocol that came into force in February 2005, with the goal of reducing developed countries emissions (Annex I) in about 5% of the levels related in the 1990's, during the 2008-2012 period. It is worth remarking that the plurality of interests of the actors, and the political divergences in negotiations have made the construction of feasible measures for the international climate changes difficult, as argued by Siqueira (2011).

In face of the difficulties related to the execution of the Kyoto agreements, Souza (2017) acknowledges that, at Conference of the Parties (COP) 15, in Copenhagen, an important point in climate change regime arises due to the new political coalitions, especially with the United States as

a protagonist (Obama government), and of Brazil, South Africa, India and China (BASIC) (SOUZA, 2017). However, it should be noted that many state and non-state actors started to influence the delimitation of the international climate change regime.

After a series of political negotiations, at COP 21(Paris), held in 2015, "196 parties to the Convention (195 countries and the European Union (EU) unanimously adopted the Paris Agreement" (IVANOVA, 2017, p. 17). One of the main goals is "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (UNFCCC, 2015, p. 3) ~~p. 1.2a).~~ The agreement came into force in November 2016, when 55 percent of responsible parties achieved 55 percent of global emissions (IVANOVA, 2017, p. 18). In the context, the Paris Agreement is considered a political success within the framework of the international climate change regime (IVANOVA, 2017, p. 18).

2. Carbon Footprint: Concepts and Empirical Studies

The origin of the carbon footprint has its roots in the 'ecological footprint' concept, proposed by Wackernagel and Rees (1996), and refers to biologically productive earth and the sea area needed to sustain a given human being population, expressed in global hectares. The usage of carbon footprint has become an important indicator the impact of the potential global warming within the environmental agenda (PANDEY et al., 2010), however, there is no consensus about the criteria used to measure it.

Wiedmann and Minx (2007, p. 4) define carbon footprint as "a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product". In other words, the authors suggest that the carbon footprint should be measured exclusively through CO2. This measurement should include activities within the individual, populations, government, corporations, industrial sectors scopes, considering both the direct and indirect emissions (WRIGHT et al., 2011, p. 63).

Although there are other substances with the potential to influence the elevation of the greenhouse effect, many of them are not originated in carbon, or are difficult to be quantified due to data availability (WIEDMANN & MINX, 2007, p. 3). Hence, Wiedmann and Minx describe two methods to measure carbon footprint: Process Analysis (PA) and Environmental Input Output Analysis (EIO). PA is a bottom-up process used to calculate the impact of a product, from its creation to its destruction. PA's focusare direct emissions, but it can also include second order impacts. On the other hand, EIO works at the economic sector level, including all economic and environmental activities. Despite all of that, EIO does not work well with microsystems, such as an individual product, but requires less resource to be processed (BREWER, 2009, p. 28).

Considering that we analyze, in this article, the carbon footprint of countries, the data we have used take into consideration all carbon dioxide emissions caused by the burning of fossil fuel in addition to the embodied carbon in imported goods. It should be noted that the Kyoto Protocol Report points out other gases that cause the Greenhouse effect, besides Carbon, such as CH4, N2O, Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and SF6. Consequently, sometimes there is concept confusion with regards to the inclusion or not of these gases in the carbon footprint (WRIGHT et al., 2011, p. 64). In this analysis, we only use the measure related to carbon dioxide.

With regards to empirical studies about carbon footprint, the research done by Hertwich and Peters (2009) reports that in highly developed countries there is a larger carbon footprint than in developing countries. This is because there is a strong correlation between the footprint and consumption expenses *per capita*. A practical example of such factors is that in several African countries, the carbon footprint, varied from one ton of carbon per person per year, while, in the United States, this variation increased to 33 tons per individual. Thus, as countries become richer, the carbon footprint inevitably rises due to the increase in consumption (HERTWICH & PETERS, 2009, p. 6415).

Hettige, Mani and Wheeler (2000) have evaluated the problem of gas emissions through an analysis of the effect of economic growth over the environmental pollution. The authors found three determinant factors: first, the industry participation in national production; second, the participation of pollutant sectors of the industrial production; third the pollution intensity per product unit of these pollutant products. From this perspective, Dinda (2004) points out that in the initial stages of development, there is a latent tendency to increase environmental pressure quicker than income, since the velocity with regards to GDP growth decreases in the higher income levels.

Similarly, Soytas, Sari e Ewing (2007) have investigated the relationship amongst energy consumption, income and carbon emissions in the USA. According to the results found, energy consumption is more relevant than income to explain CO2 emissions in the United States.

Graph 1: CO2 intensity (kg per kg of oil equivalent energy use)

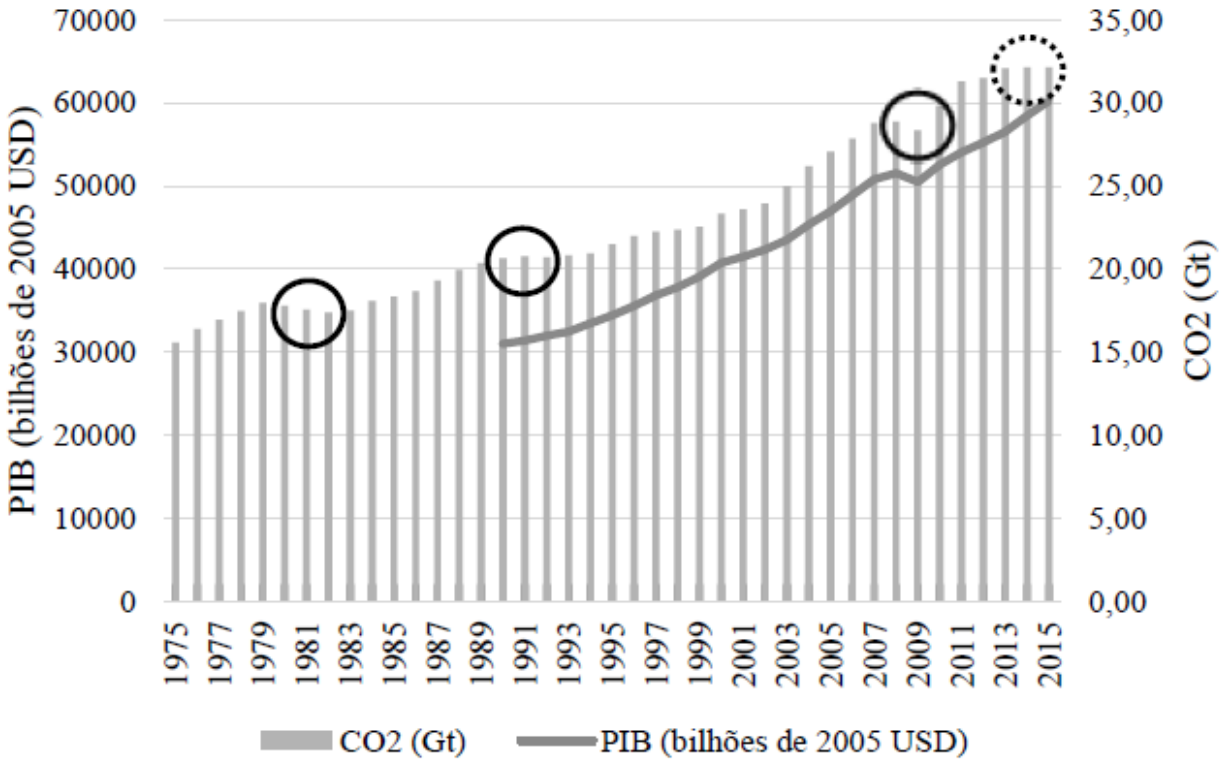
Country	2000	2008	2009	2010	2011	2012	2013	2014
United States	2,5	2,5	2,4	2,4	2,4	2,4	2,4	2,4

Source: World Development Indicators (2019).

However, according to data from the International Energy Agency (IEA, 2016), global CO2 emissions associated with energy remained stable for two consecutive years, i.e., between the years 2014 and 2015 economic growth was possible without existing an increase emissions of carbon

dioxide. Based on these data, it has been observed that in the last forty years there has been a reduction or stabilization of carbon emissions, especially in four periods. This can be explained by world crises, as observed in graph 2:

Graph 2: GDP- related CO2 emissions between 1975 and 2015



SOURCE: Lima, Machado e Rangel (2016, p. 39) based on data from the IEA (2016).

As shown in the graph 2, the decline in CO2 emissions occurred respectively in the years 1980, 1992 and 2009 due to the global crises that caused a retraction in the major economies. On the other hand, between 2014 and 2015 there was a considerable world economic growth without affecting the increase of CO2 emissions, since the generation of energy in this period came to a large extent from renewable sources, especially wind energy (LIMA et al., 2016, p. 39). The 2015 decline in energy-related CO2 emissions is due in large part to the fact that the largest emitters, China and the US, have restructured their energy matrixes. In China, low carbon sources jumped from 19% to 28% in this period, especially with the insertion of hydro and wind energy. In the US, there was a 2% decrease in CO2 emissions with the substitution of the use of coal by natural gas in the generation of electric energy (IEA, 2016).

3. Data and Methodology

As we have described previously, this research goal is to identify which variables condition countries to have a high carbon footprint. Data related to carbon footprint, GDP *per capita* and the number of signed environmental agreements were taken from the Quality of Government Dataset (Gothenburg University). To measure schooling, we have used the Human Development Index for Education that is based on the calculus of "mean years of schooling and expected years of schooling". Lastly, for democracy measurement, we have used the World Bank's 'Voice and Accountability' that takes into consideration the degree of citizen's participation in government selection, as well as expression and association freedom.

In order to analyze data, we have carried out a Qualitative Comparative Analysis (QCA), which is an application of formal logics to social sciences. Most research in the field of environmental international policy uses statistical methods, what has allowed a significant advance in the field. However, QCA offers a different approach that may bring new insights to the literature. Hypotheses generated by QCA are expressed in terms of necessary and sufficient conditions for the outcome (RIHOUX & RAGIN, 2009). Hence, new ways of looking at the problem can be unveiled through the usage of the method.

Although Set-theoretic Methods, including QCA, have gained projection due to being a good option to research with an intermediate number of cases (10-50 cases), this is not the main advantage of its usage. As Schneider and Wagemann point out (2012, p. 32), it is indispensable that the theoretical problem can be presented in terms of 'set relations', independently of the number of cases. Moreover, the larger the number of cases in QCA, the more information and precision the results yield. Thus, it is also recommended that one uses QCA to Large-N researches (THIEM, 2016). Consequently, we have decided to consider in this research all countries that had available data.

Besides the set-relation issue, QCA has three fundamental characteristics that make it different from variance-based methods (SCHNEIDER & WAGEMANN, 2012, p. 6). First, there is equifinality, i.e. the possibility of different factors to produce the same result. When one discusses sufficient conditions, normally more than one set of conditions can come together to produce the phenomenon being studied. In other words, there are multiple paths to causation. Second, there is the conjuncture causality, the possibility that singular conditions present the effect not only in isolation, but also in different combinations. Lastly, QCA also adopts the formal logic asymmetry concept that requires a separate analysis for the occurrence and absence of the outcome, since two distinct sets are necessary to analyze two different qualitative states. For instance, affirming that

democracies do not declare war amongst themselves does not entail that autocracies are more prone to get into conflict.

Considering the features presented above, one can perceive that QCA is not only a data analysis technique but also a methodological approach. Moreover, when discussing the differences of quantitative and qualitative methods, Goertz and Mahoney (2012) suggest that one should talk about two different paradigms; in other words, two different cultures. On the one hand, statistics aims at understanding 'effects-of-causes' to produce explanations; that is to measure the impact of independent variables. On the other hand, comparative methods related to the qualitative tradition, use the causes-of-effects understanding (REZENDE, 2011, p. 230) to explain what are the main determinants underlying a phenomenon; this perspective fits the scope of the carbon footprint research.

Lastly, it is worth remarking that nowadays there are many different QCA approaches. Some of the usages are intensely directed to cases, and while others focus mainly in the conditions, as is the case of our analysis. Another relevant difference is the possibility of using the method through a deductive logic to search for causal inferences or inductive logics to generate new hypotheses. As claimed by Thomann and Maggetti (2017, p. 10) QCA has also been used extensively for exploratory research with the goal of generating new insights and further theoretical development, which is the purposed of this article.

4. Results

In order to use QCA Fuzzy Set, it is necessary to calibrate conditions, which consists on the process of assigning set-membership values to cases. It is also necessary to establish the 0.5 anchor that defines whether the case belongs to the condition, as well as the full belonging and non-belonging anchors. In practice, the calibrating process transforms the raw data in a fuzzy set that varies between 0 and 1. However, it does not work as an interval scale, since there is a qualitative difference among the cases that are within and outside the set (0.5 anchor). As remarked by Charles Ragin (2008, p. 85), it is the research responsibility to establish limits according to theoretical knowledge and data reality.

In the case of GDP *per capita* as well as with the carbon footprint, we have chosen to establish the 0.5 threshold on average and to distribute cases through a logistic regression, since this solution was representative of the reality. With regards to Education HDI, we have considered 0.70 as threshold. The Voice and Accountability was collected in the ranking established by the World Bank that was maintained. With regards to international environmental agreements, we have established the signature of 100 environmental agreements as the 0.5 anchor. Cases that did not present data for any of the conditions were excluded from the analysis.

We begin the empirical analysis by testing whether any condition may be considered necessary for the occurrence of a high carbon footprint in the countries. A condition (or a set of them) is considered to be necessary when the set represented by the result is contained in given conditions. In other words, the condition is wider than the result, which appears as a subset of them. Since data used in social sciences typically present noise, it is usually not possible to make deterministic affirmations. Thus, Fuzzy-Set QCA is applicable to a probabilistic version, and thus consistency measures are applied to check the degree to which observations comply to the strict rule.

We have adopted the consistency measure suggested by Ragin (2006) that measures how much cases deviate from the necessity rule. A consistency score of 1 indicates that all cases fit with the necessity affirmation. The more cases deviate from the proposed relationship, the smaller the consistency score will be. Conventionally, a condition (or a set thereof) is considered necessary or almost always necessary if consistency is greater than the threshold of 0.9. In the table below, we performed necessity tests individually for the conditions and for all combinations amongst them.

The notation used to present conditions, conventionally, recommends that the absence of the condition be represented in lower-case letters, whereas the presence of conditions is put in upper-case letters. For instance, “GDP” means a high GDP per capita, and “voice” represents a low performance in the indicator ‘Voice and Accountability’. ‘AGREE’ e ‘EDUC’ relate to the signature of international environmental agreements and to Education HDI performance, respectively.

Table 1: Analysis of necessary conditions for a high carbon footprint

Condition	Consistency	Coverage
GDP	0.859	0.812
EDUC	0.850	0.654
VOICE	0.749	0.557
AGREE	0.624	0.623
agree	0.671	0.336
voice	0.516	0.312
gdp	0.510	0.263
educ	0.508	0.299
GDP + EDUC	0.922	0.657

+: presence of either condition or of both conditions.

Source: Own elaboration based on data from Teorell *et. al*., (2019).

When analyzing the table, one can see that no condition individually surpasses the 0.9 consistency threshold. Even out of the usual limit, the condition that becomes closer to being individually necessary for a high carbon footprint is a high GDP *per capita*, as predicted by previous statistical studies found in the literature. However, the union of the sets of a high GDP with a high performance in the educational HDI, presents itself as necessary condition for the result, given the 0.9 threshold. In other words, this means that all countries with a high carbon footprint have also a high GDP *per capita* or a high educational standard, or both conditions.

This combination coverage measure of 0.657 shows that this is a non-trivial expression. A necessary condition is trivial when it occurs in all cases, independent from the absence or presence of the result. For instance, the existence of some form of consumption in countries would be a trivial condition for a high carbon footprint and its coverage measure would be close to zero. No other condition combination simultaneously surpassed the consistency threshold of 0.9 and the coverage threshold of 0.6 in the necessity test performed.

With respect to the theoretical analysis, it was expected that the GDP *per capita* played an important role in the necessity relationship for a high carbon footprint. However, the presence of a high educational performance as part of a necessary combination for the result is a surprise in many senses. Firstly, it indicates that environmental education is not associated to ordinary education or to the number of years in school. This relation might indicate the hypothesis that the more school years in average the higher Carbon Footprint is for countries, considering the income and other factors constant.

On the other hand, it is also important to remark that one economic variable alone is not necessary for the result, but when combined to a social condition, Education, in this particular case, becomes necessary for a high carbon footprint. Thus, we highlight the importance of conjunctural causality for the study of environmental questions, since the combination of various factors may be more important than the individual condition analysis to unravel existing relationships.

In the following, we move on to sufficiency analysis. In Fuzzy-Set QCA, in order to know whether a condition (or a set thereof) is sufficient to produce the outcome, one needs to resort to a truth table (Table 2), a tool from formal logics. Although the table resembles (in appearance) a dataset, it expresses a different type of information. In truth tables, each line represents a different configuration among the possible combinations of conditions. For example, the first line of table 2 consists of countries with few signed environmental agreements, a high index at Voice and Accountability, high GDP *per capita* and high performance on the Education HDI.

At Fuzzy-Set QCA, each country partially belongs to more than one line in the table, since values between 0 and 1 were assigned to each condition. However, countries have a membership

greater to 0.5 in only one table line. Consequently, cases are distributed in the lines where they fit the best (SCHNEIDER & WAGEMANN, 2012, p. 103). A condition is considered sufficient to produce the result when, for all cases, the value of condition X in the fuzzy membership does not surpass the fuzzy membership value of the outcome (RAGIN, 2000, p. 235). The same applies to conditions resulting from set intersection ('and' connective). In summary, the sufficiency affirmation means that the condition, or the combination of them, is a subset of the result. That is, every time this condition is present, the result will also be.

Like the necessity tests, in Social Sciences, the sufficiency affirmation rarely holds for all cases. Hence, one resorts to a consistency measure. Usually, to gauge sufficiency, a limit of 0.75 is used, which was done in this research. Every line that surpasses this threshold are considered to be sufficient to produce the result, the OUT column indicates just that. Finally, the PRI column indicates the Proportional Reduction in Inconsistency, used to solve logical contradictions. The truth-table below shows the sufficiency analysis results for a high carbon footprint.

Table 2: Truth Table, outcome: high carbon footprint

	High Environmental Agreements	**High Voice and Accountability**	**High GDP per capita**	**High Education Index**	**OUT**	**Const.**	**PRI**
1	0	1	1	1	1	0.806	0.485
2	1	1	1	1	1	0.805	0.630
3	0	0	1	1	1	0.802	0.488
4	0	0	1	0	1	0.780	0.463
5	0	1	0	1	0	0.614	0.106
6	1	1	0	0	0	0.560	0.037
7	0	0	0	1	0	0.554	0.131
8	1	0	0	0	0	0.508	0.031
9	0	1	0	0	0	0.452	0.078
10	0	0	0	0	0	0.273	0.051
11	1	0	1	1	?	0.781	0.236
12	1	0	1	0	?	0.774	0.153
13	1	1	1	0	?	0.767	0.173
14	1	1	0	1	?	0.669	0.089
15	0	1	1	0	?	-	-
16	1	0	0	1	?	-	-

Source: Own elaboration based on data from Teorell *et. al*. (2019).

Four configurations are sufficient for the result: countries with high performance at the Voice and Accountability and Education HDI, high GDP *per capita* and that have signed many environmental agreements. The previous combination, without the agreements was also sufficient. The configuration of countries that did not sign many environmental agreements, low Voice and Accountability, high GDP per capita and high or low Education HDI was sufficient for a high carbon footprint according to data. Lines 15 and 16 did not present any case and are logical remainders; hence the question mark related to the result. On the other hand, lines 11, 12, 13 and 14 had less than 3 cases and were removed from the sufficiency analysis. Table 3 below shows the cases for each table line.

Table 3: Cases for each configuration

configuration	Cases
1	Bahamas, Barbados, Estonia, Israel, South Korea, Latvia, Lithuania, Singapore, Trinidad and Tobago
2	Argentina, Australia, Austria, Belgium, Bulgaria, Canada, Chile, Croatia, Cyprus, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States
3	Bahrain, Belarus, Kazakhstan, Saudi Arabia
4	Brunei, Equatorial Guinea, Gabon, Kuwait, Lebanon, Oman, Qatar, Zimbabwe, United Arab Emirates
5	Georgia, Grenada, Mauritius, Tonga
6	Mexico, Brazil, Peru
7	Armenia, Sri Lanka, Cuba, Fiji, Ukraine, Samoa
8	Marocco, Tunisia, Egypt
9	Albania, Botswana, Cape Verde, Costa Rica, Benin, Dominica, Dominican Republic, Ghana, India, Indonesia, Jamaica, Lesotho, Mongolia, St Kitts and Nevis, St Lucia, Sao Tome and Principe, South Africa, Suriname
10	Afghanistan, Algeria, Angola, Azerbaijan, Bangladesh, Bhutan, Bolivia, Bosnia and Herzegovina, Myanmar, Burundi, Cameroon, Central African Republic, Chad, China, Colombia, Comoros, Congo Democratic Republic, Ecuador, El Salvador, Ethiopia, Eritrea, Gambia, Guatemala, Guinea, Guyana, Haiti, Honduras, Iran, Iraq, Cote d'Ivoire, Jordan, Kenya, Kyrgyzstan, Laos, Liberia, Libya, Madagascar, Malawi, Malaysia, Mali, Mauritania, Moldova, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Guinea-Bissau, Rwanda, Senegal, Sierra Leone, Vietnam, Swaziland, Syria, Tajikistan, Thailand, Togo, Turkmenistan, Uganda, Tanzania, Burkina Faso, Uzbekistan, Venezuela, Yemen

Source: Own elaboration based on data from Teorell *et. al*. (2019).

In QCA, it is recommended that, to complete sufficient analysis, one performs a logical minimization of the truth table. This consists on removing everything that is logically redundant. From the analysis of the table's first and second lines, one can perceive that the signature of many environmental agreements is redundant, since the combination VOICE* GDP* EDUC is sufficient for a high carbon footprint with or without the agreements signature. Thus, this condition can be removed from the final solution. The same applies to Education with regards to the third and fourth lines. Consequently, the minimization process produces the following solution formula:

$$\text{VOICE* GDP* EDUC + agree*voice*GDP} \longrightarrow \text{CARBON} \qquad (1)$$

The formula indicates that both configurations are sufficient for a high carbon footprint both individually and together. In other words, whenever one of the two parts is present, the result will occur. The first combination is of countries with high Voice and Accountability, high GDP *per capita* and high Education HDI. In a sense, it was expected that rich, democratic and with favorable social indexes presented a high carbon footprint, due to their history of consumption, industrialization and carbon emissions. Although European countries that industrialized before the XX Century are in this combination, such as the United Kingdom, France and Belgium, there are other categories encompassed in this part of the solution. There are the ex-Soviet Union Countries, such as Poland, Belarus and Estonia, as well as countries form the Global South, such as Argentina and Chile.

The second configuration in the formula consists of countries that have signed few environmental agreements, have low citizen participation in government selection and a high GDP *per capita*. Those include, especially, big oil producers, such as Kuwait, Bahrein, Saudi Arabia and Qatar, besides other dictatorships that have a GDP per capita above global average. It is worth remarking that, although, the GDP per capita plays a fundamental role in the analysis, conditions related to environmental agreements and democracy have been shown to be important to explain the result. Thus, hypotheses that involve internal political variables should be incorporated to analysis models to understand processes that lead to a high carbon footprint. Table 4 shows consistency and coverage of each part of the solution.

Table 4: Sufficient combination of conditions for high carbon footprint

Conservative Solution	**Consistency**	**Raw Coverage**	**Unique Coverage**
VOICE*GDP*EDUC	0.813	0.674	0.416
agree*voice*GDP	0.797	0.404	0.146
Solution Consistency	0.820		
Solution Coverage	0.820		

Source: Own elaboration based on data from Teorell *et. al*., (2019).

The consistency of both configurations is greater than 0.75, whereas the full solution presents 0.820, which demonstrate the robustness of the results found. The Raw Coverage refers to the size of the overlap between the size of the combination set and the outcome set relative to the size of the outcome set (RAGIN, 2006, p. 301). The unique coverage, on its turn, refers to the cases that are explained solely by that combination, since many cases may be explained by more than one way or solution combination. In summary, coverage refers to how much of the outcome is being explained. The VOICE*GDP*EDUC combination has shown a greater explanatory power than the other part. However, the agree*voice*GDP combination is also relevant for a high carbon footprint.

It would also be possible to further minimize the truth table, in case the remaining logical remainder lines were included. To reach an intermediate solution, one must include the theoretical expectations of how each condition interacts with the outcome, whether it tends to increase or decrease, in the analysis. However, since this research is an explanatory analysis, we have chosen not to perform minimization until the intermediate solution and work only with the conservative solution presented above.

Conclusions

The Fuzzy-Set QCA choice as an inductive method to generate significant results has shown valid. Characteristics of complex causality were not only present but were also fundamental for reaching possible explanations for a high carbon footprint. For instance, equifinality was an important tool, since data analysis demonstrated two ways to reach the outcome. The conjunctural causality has also been essential, since no singular condition was consistent within the conventional parameters for consistency, nor within the necessity analysis nor within sufficiency analysis. On the other hand, the combination of different conditions has presented significant results.

The insertion of a domestic and international political variable has also indicated a relevant effect. The condition related to high internal politics openness was associated to high GDP *per capita* and to high Education performance in order to be sufficient for a high carbon footprint. This configuration is not surprising, inasmuch as these are characteristics of industrialized European countries that historically possess a high carbon footprint. However, the second combination sufficient to produce the result, a high GDP per capita, the signature of few environmental agreements and limited internal politics openness is an important indicator for the literature. Data shown that every time this configuration is presented, there is also a high carbon footprint, considering the conventional consistency measure.

Future research may carry out case studies about countries that present this second combination, with the aim of understanding the mechanisms that connect conditions and outcome.

In this context, most previous studies focus mainly on economic variables. Although GDP per capita is present in both solution combinations, according to data, one cannot infer that this condition is sufficient for a high carbon footprint. In summary, the various configurations found in the sufficiency analysis confirm that internal and international political conditions are important for the analysis.

However, it is important to consider that we expected GDP per capita to play an important role, however its association to the high performance on Education GDP, through the logical connective 'or' as a necessary condition to the outcome is a surprise. This finding indicates that more school years do not entail a positive impact in environmental education.

Although we recognize the panoramic nature in terms of the number of countries included in the analysis, it's an initial step towards the development of new research, such as the selection of case studies and inclusion of new variables. In these terms, we recommend that to assess the education impact on the carbon footprint, one should use not only configurational methods, but also statistical ones. The hypothesis may also be formulated in terms of variance-based methods, since one can investigate whether more school years are correlated to a higher carbon footprint, keeping the other variables constant.

The mechanisms underlying this relationship may also be the object of conjectures, because it is possible to assume that, in this case, the school years effect may be the reflex of a greater appetite for consumption. Although this conjecture is not completely new, it is not necessarily intuitive, since one would expect that more educationally developed populations may find solutions for the social conundrums more easily. In any case, if this hypothesis is corroborated in future studies, this may entail a need for reflection and change in the organization of the educational system as we know it.

Finally, we should remark that this research did not aim to answer the questions proposed in the literature, but instead to suggest new paths for the field of International Environmental Politics, in the study of the causes of high carbon footprint. With that, we believe that the use of Fuzzy-Set QCA has brought about new insights that should be examined by future research.

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