

ENVIRONMENTAL MANAGEMENT & CONSERVATION | RESEARCH ARTICLE

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Cogent Environmental Science (2017), 3: 1420365



Received: 26 July 2017
Accepted: 17 December 2017
First Published: 23 December 2017

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Reviewing editor:
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Developing CBDR-RC indices for fair allocation of emission reduction responsibilities and capabilities across countries

Izzet Ari^{1*} and Ramazan Sari^{2,3}

Abstract: The aim of this paper is to develop two indices for quantifying common but differentiated responsibilities (CBDR) and respective capabilities (RC) of countries in mitigating climate change. These composite indices can help facilitate fair allocation of GHG emission reduction responsibilities across countries. Indices are formulated by taking into account the economic, environmental, social, and technical indicators of a given country. These indicators are usually highly correlated. An index using these indicators must take this high correlation into account, otherwise it will either over or underestimate the responsibility and the capability of a country. This study takes the correlation between the indicators into account in developing the CBDR and RC indices via the principal components method. However, the novelty of this study arises from measuring and using economic, social, technical, and environmental indicators together in creating the composite indices. The CBDR and RC are constructed for 50 countries that are responsible for at least 81% of global GHG emissions, including OECD countries and emerging economies. The Cluster Analyses



Ramazan Sari & Izzet Ari

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PUBLIC INTEREST STATEMENT

The Paris agreement entered into force in 2016. The Agreement aims to strengthen the global response to the threat of climate change, in the context of sustainable development. The Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities (CBDR) and respective capabilities (RC). Responsibilities and capabilities are determined as developed and developing countries in the Agreement. However, there is no clear classification for those countries. This article creates a tool to understand the level of responsibility (CBDR) and capability (RC). It was found that definitions of developed and developing countries should not be based on static, already done within the United Nations Framework Convention on Climate Change and historical emissions. Usage of economic, social, technical, and environmental dimensions of development can improve understanding of definitions on developed and developing countries.

are employed to classify the countries according to their CBDR and RC scores. The results suggest revision of current responsibility and capability classifications of the UNFCCC.

Subjects: Development Studies; Sustainable Development; Environment & the Developing World

Keywords: CBDR and RC principle; principal component analysis; cluster analysis

1. Introduction

According to the UNFCCC, countries should protect the global climate system on the basis of equity and in accordance with their common but differentiated responsibilities (CBDR) and respective capabilities (RC) (UNFCCC, 1992). Thus, all countries share a common set of responsibility frame, but the responsibilities are differentiated according to the differing capabilities of each country (Basic, 2007; UNFCCC, 1992). The UNFCCC suggests that emission mitigation efforts should also be taken by non-Annex I countries in line with their capabilities. However, non-Annex I countries have not taken any quantified emission mitigation targets, according to their responsibilities and respective capabilities. While developing countries have blamed the developed countries for their past emissions in the context of historical responsibilities, developed countries have invited developing countries to take serious actions in accordance with CBDR (Dubash, 2009). However, this polarized situation and tension between developed and developing countries hinders reaching the objective of the UNFCCC, and leads to failed climate agreement attempts such as the Copenhagen Accord in 2009 (Dubash, 2009).

At the Conference of Parties (COP) of the UNFCCC in 2011 (COP-17), a new negotiation platform, the *Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP)*, was established in order to construct a post-2020 international climate regime. ADP opens a venue for developing countries to be involved in emission mitigation, since the ADP's mandate encourages inclusion of all parties without Annex-I/non-Annex I, developed/developing separations (UNFCCC, 2012). It is expected that non-Annex I countries will contribute to emission reduction in the post-2020 climate regime through the ADP process significantly (Aldy & Stavins, 2012).

In 2015, 21st Conference of Parties (COP-21) of the UNFCCC has adopted a new legal document called the Paris Agreement. This Agreement categorizes countries' responsibilities as developed and developing countries rather than Annexes system of the UNFCCC. However, developed and developing countries are not defined in the agreement. This undefined classification might cause problems during the implementation of the Paris Agreement. One of the problem might be about countries' resistance on keeping *state que* rather than ensuring fair burden sharing on emission reduction. Copenhagen Climate Summit in 2009 was a well known example for the similar problem. Lesson learned from the failure of Copenhagen Summit showed that non-Annex countries resisted to take emission mitigation targets even many of them have higher capabilities and responsibilities than Annex-I countries (Ari & Sari, 2015). Besides, they blamed Annex-I countries for their insufficient efforts as required in the UNFCCC and the Kyoto Protocol, and prefer to keep the existing classifications of the UNFCCC. This resistance caused problems of unfair allocation of responsibilities among countries. Thus, the resistance from non-Annex countries and insufficient efforts of Annex-I have led to a failure progress in the climate change negotiations for the post-2012 regime (Dubash, 2009).

In terms of ensuring equity and operationalization of the principle of CBDR-RC, all countries ratification of the Paris Agreement will be an opportunity, but allocation of emission reduction among all countries particularly developed and developing countries should be fair. For instance, in the Article 4 of the Paris Agreement, while developed countries should continue taking the lead by absolute emission reduction targets, developing country should reduce their emissions in the light of different national circumstances (UNFCCC, 2015). In this case, the undefined terms of "developed" and "developing" countries might result in referring back to the Annexes of the UNFCCC (Stavins & Stowe, 2016). Thus, the persisting in the Annex system of the UNFCCC, while implementing the Paris

Agreement, might break the deal of the adopted Agreement even entered into force in 2016. This might cause another problem. It is clear that before the implementation of the Paris Agreement, there is a need for a guidance, rules, and procedure for definition of developed and developing countries.

Besides the necessity of updating the UNFCCC's annexes, the main principles of the UNFCCC, such as CBDR and RC, are needed to be analyzed to find a common and objective ground for revision of the current allocation of responsibilities (Bodansky, 2012; Heyward, 2007). Although many differentiation proposals have been submitted from countries or scholars to find a true position for countries (Bodansky, Chou, & Jorge-tresolini, 2004; Karousakis, Guay, & Philibert, 2008; Wei, Zou, Wang, Yi, & Wang, 2013), none of them directly use the operationalized and quantified CBDR and RC in their differentiation proposals. To better represent and utilize country-specific characteristics, CBDR and RC must be quantified. For the purpose of quantification, composite indices need to be constructed. The main reason behind creating separated responsibility (CBDR) and capability (RC) indices is to determine countries' true responsibility and capability level. For example, a big emitter country is expected to be one of the most responsible party, but the country might not have capabilities to overcome to reduce its emissions. Similarly, a country with low responsibility might assist to other countries according to its capability level.

The aim of this paper is to construct, for first time, composite indices for CBDR and RC in order to differentiate countries' positions. These indices are formed based on selected indicators that represent different dimensions of responsibility and capability. In addition to the commonly used economic and environmental indicators, social and technical indicators are also used in the construction of indices. Social and technical indicators were not quantitatively considered in the literature previously. Technical variables indicate whether countries are capable of climate change mitigation without hindering their economic growth, and social variables indicate perceptions and abilities of societies' for the mitigation policy shift. As emphasized in the latest IPCC report, the causes and effects of climate change are varying in developed and developing countries depending on social capital such as education and awareness level of society, customs and cultural dimensions for social acceptability, ability for collective action and coordination in a country, and degree of equality (Kolstad et al., 2014). Social concerns and opportunities such as education, health care, sustainable environment, and social lives, that are complementary to economic issues, are related to capability, level of development, and quality of life in a country (Sen, 1999). Social variables can explain public perceptions and social transformation abilities in response to mitigation policies. These social variables should be included in the set of determinants of effective environmental policies. Economic and technical indicators alone do not sufficiently reflect mitigation capabilities of a country. Social indicators must be accounted for in assessing potential national contribution to climate change mitigation.

The challenge is the determination of appropriate indicators and methods for computing CBDR and RC indexes. The candidate indicators are highly correlated, thus, a methodology that can overcome this problem should be employed. The Principles Component Analysis (PCA) is employed to eliminate the effects of highly correlated indicators when accounting for the total variation covered by all indicators. The Cluster Analyses (CLA) technique will then serve to classify countries into natural groups based on CBDR and RC index scores. The data are limited to 50 most emitting countries, including all OECD member states, emerging economies such as China, Brazil, South Africa, India, Indonesia, and Malaysia as well as economies in transition countries. The selected 50 countries are responsible for at least 81% of global GHG emissions according to 2010 (WRI, 2014).

2. Conceptual framework

The climate change is a tragedy of the commons problem (Hardin, 1968) since a country's emissions affects the whole globe, and an emission reduction by a country benefits all countries (Kolstad et al., 2014). Besides, climate change is still an important global problem that has not been solved through the allocation of responsibilities based on current annexes of the UNFCCC. To reach the ultimate

objective of the UNFCCC, more efforts are required. But the question of “how should effort or burden sharing among countries be done?” raises the difficult concerns of climate equity, justice, fairness, and rights (Kolstad et al., 2014).

2.1. Responsibility

Allocation of responsibility is the most important point of equity in the context of climate change (Ashton & Wang, 2003). The responsibility for climate change has scientific, political, and ethical dimensions (Wei et al., 2013). However, the determination of responsibilities in terms of scientific and moral concerns is quite difficult (Heyward, 2007). Although several proposals for quantifying countries’ causal or moral responsibilities have been made (Füssel, 2010), there is no consensus on how to define responsibility (Weisbach, 2010).

Responsibility theories deal with protecting sufferers from others’ wrong actions (Weisbach, 2010). The principle of polluter pays, which is based on addressing climate change problem in line with accountability for the consequences of the problem, distributes efforts as a compensation tool by sharing responsibilities in accordance with contribution to the problem (Ashton & Wang, 2003; Heyward, 2007; Rive & Fuglestedt, 2008). Polluter pays principle is based on the ethical notion that *thou shalt not harm others* or at least not harm others “knowingly” (Mattoo & Subramanian, 2012). In other words, any polluter who is conscious about the damage he/she has caused should have greater responsibility than others who are not aware of the consequences of their actions (Ashton & Wang, 2003).

2.2. Capability

Capability is highly related to the welfare, technology, institutions, skills, information, and opportunities in a society. It is expected that developed countries have more capacity to address the problem (Ashton & Wang, 2003). During the negotiations under the ADP, for instance, many countries’ and NGOs’ stressed the relationship between commitments and RC (IISD, 2012; Müller & Mahadeva, 2013). The concerns were based on the impossibility of success in the climate change negotiations without appropriately and fairly considering the RC. When considering the importance of GDP in the determination of capability, increasing capacity in terms of per capita GDP is strongly associated with high emissions and high per capita emissions (Aslam, 2002). However, capability is not only related to per capita GDP and per capita emission, but also related to social, technological, and institutional factors (Winkler, Baumert, Blanchard, Burch, & Robinson, 2007). For capability, Müller and Mahadeva (2013) propose a new framework, known as “The Oxford Approach”, to measure countries’ ability to pay for climate change on the basis of income tax paradigm. Müller and Mahadeva (2013) modify GDP in terms of relative prosperity levels, which are determined by the taxable income, and obtain the gross taxable income based on the general ability to pay. However, they only handle the economic dimension of the RC. The technological and social dimensions should also be integrated into economic dimensions holistically, because un-advanced technological level may hinder the economic growth and/or negative attitude may prevent the necessary social support during the implementation of environmental policies.

The differentiation of commitments and contributions in the light of national circumstances, the principle of CBDR and RC were reiterated in the Paris Agreement. Therefore, the representation of the countries’ national circumstances through quantification of related indicators gains a significant importance for reflecting equity and the principle of the CBDR and RC in nationally determined contributions including emission reductions and providing finance. Thus, there is an urgent need to accurately use CBDR and RC to assess the INDC of each country. Therefore, objectively quantified CBDR and RC criteria can be useful for policy-makers and negotiators.

3. Data and methodology

To quantify CBDR and RC and to assess countries’ emission mitigation responsibilities, a set of economic, social, technological, and environmental variables are used. By utilizing these indicators, CBDR Index and RC Index are created to compare responsibilities and capabilities of countries. Additionally,

countries are classified into groups using the calculated CBDR and RC indices. The scope of the analysis is limited to 50 countries because of availability of data for these countries.

3.1. Creating composite indices

Composite indices provide simple comparisons of countries by creating an index in a wide-ranging field, e.g. environment, economy, society, or technology (Nardo et al., 2008). In the climate change literature, different types of indicators have been selected to explain countries' emissions profile, responsibilities, abilities, and performances to combat climate change. Without considering multi-dimensional aspects, only emission related and economic indicators might not be sufficient to reflect countries' national circumstances. Therefore, all relevant aspects of responsibility and capability such as economic, emission, social, and technical indicators are attempted to include in this study (Table 1). This section consists of two parts: variables for CBDR and variables for RC.

3.1.1. Variables for CBDR index

Total GHG emissions, per capita GHG emissions, change of per capita GHG emissions, change of GHG emissions per unit GDP, cumulative CO₂ since 1850, cumulative GHG since 1990, consumption-based per capita CO₂ emissions, and sectoral per capita GHG emissions are used as indicators. Besides basic emission indicators such as annual, historical emissions and per capita emissions, sectoral and consumption-based per capita emission indicators are also used. It is assumed that sectoral emissions can provide countries' sector-specific emission intensities. In climate change negotiations, not only economy-wide emission reduction, but also sectoral emission reduction targets for countries have been discussed. For this reason, energy, industry, agriculture, and waste per capita emissions are considered in the calculation of CBDR index. Besides domestic or production-based GHG emissions in a country, some studies emphasize on relations among consumption, trade, and national GHG emissions budgets (Wiedmann, 2009). In the climate policy literature, it is suggested that consumption-based GHG emission accounting should be concerned as a necessary tool (Peters, 2008). Since emissions embodied in trade and consumption are rapidly increasing, there is a growing gap

Table 1. CBDR and RC indicators

CBDR	Responsibility	GHG emissions
		Per capita GHG emissions
		Consumption-based per capita CO ₂ emissions
		Sectoral per capita emissions
		Cumulative emissions since 1850 and 1990
		Change of per capita emissions
		Change of GHG emissions per GDP
		GHG emissions per GDP
RC	Economic	GDP
		Gross savings
		Per capita GDP
	Social	Literacy rate
		Unemployment rate
		Income inequality
		Poverty rate
		Secondary school enrollment
	Technical	Number of hospital beds
		High technological export
		Research and development expenditure
		Renewable energy

between production emissions and the emissions associated with consumption (Barrett et al., 2013). The coverage of consumption-based GHG emissions is the inclusion of GHG emission associated with products and services in a country where they are consumed, and exclusion of GHG emissions related to exported products (Csutora & Vetőné mőzner, 2014). Therefore, the needs for adoption of consumption-based GHG emissions accounting has started to be discussed in the climate policy domain (Kokoni & Skea, 2013). While creating CBDR index, emission intensity indicators such as change of emission intensity of economy are also used. The change of GHG emissions per unit GDP for a country gives information about the tendency of emission intensity of the economy. For instance, some countries can follow more climate-friendly or less carbon intense growth path; as the change is negative, the country's efforts positively affects to reduce its responsibility. When the intensity is high, it means that the economy has emission intense structure or production style; so its responsibility can increase due to the emission intense economy.

3.1.2. Variables for RC index

RC has economic, technological, and social capability dimensions. Economic capabilities can be represented by GDP, per capita GDP, and the percentage of gross savings in the GDP. Technical capabilities can be based on the share of research and development (R&D) expenditure in GDP, patents number in one million people, the share of high technology exported products in total manufactured products, and the usage of renewable energy sources as primary energy sources in the total energy supplies. For social capabilities, literacy rate, unemployment rate, Gini Coefficient to measure the income inequality, poverty rate, and hospital bed for per 10,000 people can be taken into account. Economic indicators might be considered as the main indicators for determination of capability, however, social and technical dimensions should also be included to ensure multi-dimensionality of capability issue.

As a technical capability indicator, technological and scientific research and development (R&D) are necessary for innovative solutions to combat climate change. According to the IPCC's report, it is almost impossible to stabilize GHG emissions in the atmosphere without R&D (Edenhofer et al., 2014). Related to R&D expenditure and other technical infrastructure of a country, patent number can show the efficiency of R&D expenditure, technological and scientific institutions for being ready to deployment of technologies in the context of mitigation of GHG emissions. To reduce emissions, innovative and high-tech products can play a critical role. Increasing output efficiency in manufacturing industries, replacing old-fashioned production style with more climate-friendly and sustainable production styles, and solving the complicated problems depend on owning of high technological products in a country. High technological production capabilities in any country can also indicate countries' intellectual knowledge and innovations to overcome climate problems. In terms of technical capabilities, there are many types of technologies reducing GHG emissions through alternating fossil fuels with renewable energy sources (Edenhofer et al., 2014). In fact, many studies consider the renewable energy sources as one of the main solutions to mitigate GHG emissions (IEA, 2013; IPCC, 2011).

As it is needed to expand emission mitigation activities to all societies, consumer behavior and basic knowledge are highly critical to follow countries' emission reduction policies at the individual level. Literacy rate in a society can be used as a proxy for countries' capacity deficiency in terms of general knowledge on emission reduction policies. Education is an essential ingredient of a society to combat climate change to raise awareness and realize long-term targets. Transformation of societies from traditional to new development pathway is positively related to the level of education. Education level is a part of social capital (Fleurbaey et al., 2014). In this study, total enrollment in secondary school education is used as one of the measurements of social capability. Improved education level of a country can enlarge the capacity of mitigation to combat climate change (UN, 2014). Similar to education level, the employment rate can be considered as a social capital in the national circumstances; so, the unemployment rate can provide information about country's general socioeconomic situation as well. Number of hospital beds as an indicator can represent the different aspects of social capabilities. This variable, as a component of the health care system, can

provide information about the existence and sufficiency of social opportunity in a country (Sen, 1999). A rise in the temperature has negative impacts on human health, water resources, agricultural productivity, and energy use (USGCRP, 2017). Younus (2017a) quantifies impact of extreme climatic events on communities. Creating a weighted index for vulnerability and adaptation levels of societies can assist to evaluate the impact of extreme weather events on local communities and to come up with new policies for reducing future vulnerability (Younus, 2017a). Adaptation to climate change is a very important subject for developing countries because the actions involved are highly essential in improving the resilience of a developing society (Younus, 2017b). Developed countries should assist developing countries in the context of adaptation through providing financial resources, transferring technology, and capacity-building (Younus, 2017b).

Social capabilities and resilience in case of any natural disaster can depend on ability to recover the impacts of the disaster. For instance, heat waves in Europe in 2003 caused many health, agricultural, and infrastructure problems (Schar et al., 2004; Stott, Stone, & Allen, 2004). Income inequality can be considered as a measure of the development level of a country (Baer, Kartha, Athanasiou, & Kemp-Benedict, 2008). It can also provide information about the emission distribution within a country between different income levels (Fleurbaey et al., 2014). Social capability is a part of the development issue. In designating a development threshold, each country's income distribution is an essential indicator. The Gini coefficient indicates the level of social welfare linked to the income distribution, which may have an impact on the capacity of effective integration to environmental policies. Besides, decreasing income inequality is among the Sustainable Development Goals (SDG-10: Reduce inequality within and among countries) to sustain social prosperity. Additionally, poverty which is a kind of shortage of income, causes deprivation of basic capabilities (Sen, 1999). Because climate change is a multi-dimensional issue, and any country with high poverty rate can be less capable to reduce GHG emissions.

3.2. Normalization of indicators

Indicators can have different measuring units and scales, so they should be normalized in a common scale before starting the weighting and aggregation steps of index development (Nardo et al., 2008). There are different types of normalization methods such as min-max, standardization (z-scores), ranking, and categorical scales. Standardization (z-scores) technique is used in this study. In order to obtain each normalized indicator, I_k , the average of X_k , μ , and standard deviation, σ , are used as shown below.

$$I_k = \frac{X_k - \mu}{\sigma} \quad (1)$$

3.3. Principal component analysis

After the normalization of the indicators, the following step is the employment of PCA. The aim of the PCA is to reduce the large number of variables into a smaller number of components that represents most of the variance in the variables (Verma, 2013). PCA attempts to maximize correlation between original variables and new components, and among new components ensures non-correlation and orthogonality (Ul-Saufie, Yahaya, Ramli, Rosaida, & Hamid, 2013). After new components are obtained from the original data, PCA provides a new formula with a new source of variation as formalized below:

$$PC_i = I_{1i}X_1 + I_{2i}X_2 + \dots + I_{ni}X_n \quad (2)$$

where PC_i is i^{th} principal component and I_{ji} is the loading of the observed variable X_j .

In the PCA, new components are linear combinations of the original variables, and the levels of these new variables are known as eigenvalues. An eigenvalue is a ratio between the common variance and the specific variance explained by a specific factor extracted (Ho, 2006). When all eigenvalues are summed, they are equal to the number of variables (Verma, 2013). Kaiser's Criteria are used to determine the number of eigenvalues. This Criteria suggests that the eigenvalues greater than 1.0 should stay in the analysis (Abson, Dougill, & Stringer, 2012; Verma, 2013). While determining new

components, there are a bunch of techniques for rotation including varimax, quartimax, equamax, direct oblimin, and promax. The varimax rotation technique is commonly used in the PCA (Verma, 2013). It is an orthogonal rotation of the component axes to maximize the variance of the squared loadings of a component on all variables in a component matrix (Verma, 2013). The criteria to check the variables in terms of suitability of PCA are The Kaiser–Mayer–Olkin (KMO) sampling adequacy test and Bartlett’s sphericity tests (Abson et al., 2012). KMO test result should be higher than 0.500 and Bartlett’s sphericity tests should be less than 0.05 for all PCA analyses (Abson et al., 2012).

All CBDR indicators are utilized by PCA to find a number of principal components for calculations of CBDR index. Similar steps are also followed for RC index development. The results of the PCA are expected to provide a number of principal components and weights of each principal component as follows:

$$I_{\text{CBDR}} = \sum_{j=1}^m \gamma_j PC_j \quad (3a)$$

$$I_{\text{RC}} = \sum_{j=1}^m \gamma_j PC_j \quad (3b)$$

where,

$$\gamma_j = \frac{\text{eigen value}_j}{\sum_{j=1}^m \text{eigenvalue}_j} \quad (4)$$

I_{CBDR} is the CBDR index, I_{RC} is the RC index, γ_j is the weight of j^{th} principal components, and PC is the principal component.

3.4. Cluster analysis

Cluster analysis (CLA) is employed to classify 50 countries based on CBDR and RC index scores. The aim of CLA is to group countries by the similarity of index values, so a group or cluster consists of homogenous and similar variables or subjects (Anderberg, 1973). The similarity is measured by the distance among the cases or objects. The most common and simple measurement of distance method is the Euclidean distance. After the measurement of distances, the linkage procedure of the cases should be selected. There are three different procedures to do this: hierarchical clustering, non-hierarchical clustering, and two-step clustering (Verma, 2013). The hierarchical classification, which can be presented via tree clustering in CLA, is based on distance measurement among cases (Nardo et al., 2008). In order to form a cluster within the hierarchical clustering procedure; there are centroid, variance (Ward), and linkage methods. In the centroid method, the cluster is formed on the basis of the Euclidian distance among cluster centroids; in the variance method, the cluster is formed in order to minimize the within-cluster-variance; and in the linkage method the cluster is formed on the basis of minimum distance between closest/farthest/average of member of clusters (Verma, 2013). In this study, Ward’s minimum variance method with squared Euclidian distance measurement technique is used to ensure the most probable homogeneous clusters. Classification and grouping of all 50 countries using CLA can provide appropriate segregation among groups without losing any information in index scores.

4. Results

4.1. Results for CBDR index

Before creating CBDR index, KMO and Bartlett’s sphericity tests are conducted for PCA. The findings suggest that the KMO is 0.525, and Bartlett’s test is smaller than 0.05, so PCA can be applied. The next step is to determine the number of principal components. The PCA results indicate that there are

Table 2. The principal components for CBDR index

Principal components	Eigenvalues	γ
1	2.912	0.503
2	1.764	0.305
3	1.111	0.192

three principal components, explaining 82.7% of total variation.¹ In order to find weights of each principal component in the CBDR index, ratio of each eigenvalues to total eigenvalues are calculated (Equation (3a)). Thus, the weights of each principal component symbolized by “ γ ” are listed in Table 2. The sum of principal component weights must be 1.0.

To find CBDR index, each principal component is multiplied by its corresponding weights (γ) (Equation (3a)). The calculated index scores are provided in Table 3. Once an index for each country is calculated, then countries are grouped using CLA methodology (Column 4). The CBDR indices indicate that the USA is the most responsible country, and Philippines is the least responsible country for climate change among the 50 countries. The CLA results suggest that countries in Group-A have the highest, and Group-E the lowest responsibility to mitigate emissions.

Table 3. CBDR index scores and country groups

Rank	Country	CBDR index	Group
1	USA	2.447	A
2	Australia	1.501	B
3	Canada	1.098	B
4	Russia	0.887	B
5	Saudi Arabia	0.865	B
6	China	0.818	B
7	Estonia	0.548	C
8	New Zealand	0.535	C
9	South Korea	0.426	C
10	Finland	0.405	C
11	Israel	0.348	C
12	Ireland	0.222	C
13	South Afr.	0.165	C
14	Germany	0.162	C
15	Czech Rep	0.147	C
16	Belgium	0.142	C
17	Malaysia	0.104	C
18	Japan	0.066	C
19	Netherlands	0.052	C
20	Singapore	0.039	C
21	Greece	0.031	C
22	Argentina	0.013	C
23	UK	-0.054	D
24	Norway	-0.085	D
25	Denmark	-0.088	D
26	Poland	-0.132	D

(Continued)

Table 3. (Continued)

Rank	Country	CBDR index	Group
27	Austria	-0.138	D
28	Slovenia	-0.163	D
29	Italy	-0.197	D
30	Portugal	-0.225	D
31	Iceland	-0.229	D
32	Bulgaria	-0.230	D
33	France	-0.269	D
34	Mexico	-0.280	D
35	Spain	-0.289	D
36	Slovakia	-0.375	E
37	Malta	-0.389	E
38	Lithuania	-0.437	E
39	Hungary	-0.466	E
40	Brazil	-0.474	E
41	Turkey	-0.485	E
42	Switzerland	-0.505	E
43	Romania	-0.556	E
44	Thailand	-0.572	E
45	Sweden	-0.580	E
46	Latvia	-0.621	E
47	India	-0.708	E
48	Chile	-0.719	E
49	Indonesia	-0.723	E
50	Philippines	-1.035	E

The map illustrated in Figure 1 presents the distribution of countries based on CBDR index scores. There is no visible convergence in terms of institutional perspective such as being an OECD member state or not. Likewise, there is no clear distinction between Annex-I and non-Annex I countries of the UNFCCC. Yet, except China and Saudi Arabia, the North-South division still exists in the map. There is no country from Southern part located in Group A. Nevertheless, the Northern countries are not as homogenous as the Southern countries in terms of responsibility issue. For instance, the European countries can be observed in Group B, C, D, and E. Further differentiation among the Northern and the Southern countries are required. It seems that the results indicate a new group emerging in the same cluster, consisting of Canada, Russia, Saudi Arabia, and Australia. The index of these countries is closer to each other, and yet they have different economic levels but they still should take similar emission mitigation commitments. All these results indicate that the current classification based on Annexes or institutional criterion according to the early 1990s may fail to be used in determination of countries' emission mitigation responsibilities. Also, any differentiation referring to the existing grouping criterion such as being an OECD member states or G/77 + China countries highly likely leads to incorrect classification.

4.2. Results for RC index

The test statistics of 0.683 for KMO and 0.05 for Barlett's test indicate the applicability of the PCA. Results suggest that four principal components explain 67.67% of total variation. In order to determine weights of each principal component in the RC index, ratio of each eigenvalues to total eigenvalues are calculated as in Equation (3b). The weights of each principal's coefficient shown with "γ" are presented in Table 4.

Figure 1. The world map based on CBR index.

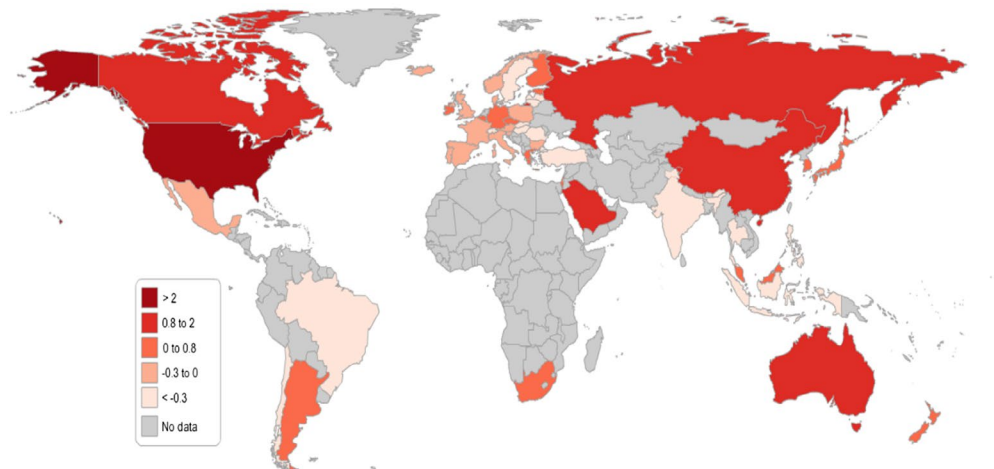


Table 4. The principal component for RC index

Principal component	Eigenvalues	γ
1	3.591	0.442
2	2.192	0.267
3	1.320	0.163
4	1.018	0.125

Using Equation (3b), RC indices are calculated and then the CLA methodology is employed to determine country groups, as shown in Table 5. The RC index scores indicate that Singapore is the most capable and South Africa is the least capable country to combat climate change among the 50 countries. The CLA results suggest that there are five groups. In Group A, there are five countries and two of them are non-Annex I countries. On the other hand, in Group-E, there are five countries and only two of them are Annex-I countries (Turkey and Greece).

The world map in Figure 2 illustrates countries based on RC index scores. In terms of continental perspective, while North American Countries such as Canada and the USA are in the same group, it is not the similar case among Latin American countries. The EU countries donot have same capability level. In terms of institutional perspective, the OECD member states do not resemble each other. Also, there is no clear divergence between Annex-I and non-Annex I countries. Except, South Korea, all the Southern countries analyzed in this study have lower capabilities than many Northern countries. It seems that the current classifications of countries may address to the climate change problem when it comes to emission mitigation capabilities of countries.

There are four regions in the Figure 3. Countries in the *first* area with low RC and CBR index values are not only less responsible, but also have low capability for emission mitigation. Whatever these countries' classifications are in the UNFCCC, their reduction targets should be the lowest among 50 countries selected. Although India is one of the biggest emitter, it has low CBR and RC index scores. The position of India becomes clearer when compared to first method's indices scores. Countries in the *second* area with high RC and low CBR are less responsible, but highly prosperous countries. Countries in this area do not need to take high reduction commitments, but they should assist to other countries through providing finance and technology transfer. The *third* area represents countries with high RC and high CBR. Countries in this area should commit for both emission reduction and finance, technology transfer and capacity-building to other countries. They should also lead in combating climate change. Countries in the fourth area with low RC and high CBR have high

Table 5. RC index scores and country groups

Rank	Country	RC index	Group
1	Singapore	1.296	A
2	Japan	1.100	A
3	South Korea	1.005	A
4	Norway	0.794	A
5	Australia	0.748	A
6	Switzerland	0.612	B
7	Finland	0.569	B
8	Iceland	0.543	B
9	Sweden	0.532	B
10	Austria	0.499	B
11	USA	0.490	B
12	Netherlands	0.461	B
13	Germany	0.446	B
14	New Zealand	0.380	B
15	Denmark	0.353	B
16	Canada	0.351	B
17	France	0.350	B
18	Israel	0.220	C
19	Belgium	0.184	C
20	China	0.162	C
21	Ireland	0.127	C
22	Malaysia	0.079	C
23	UK	0.076	C
24	Czech Rep	0.053	C
25	Malta	0.047	C
26	Slovenia	-0.004	C
27	Russia	-0.029	C
28	Hungary	-0.085	C
29	Estonia	-0.151	D
30	Italy	-0.174	D
31	Thailand	-0.213	D
32	Poland	-0.278	D
33	Lithuania	-0.293	D
34	Romania	-0.360	D
35	Latvia	-0.374	D
36	Philippines	-0.401	D
37	Saudi Arabia	-0.417	D
38	Slovakia	-0.453	D
39	Portugal	-0.495	D
40	Spain	-0.498	D
41	Indonesia	-0.510	D
42	Chile	-0.514	D
43	Brazil	-0.534	D
44	Argentina	-0.602	D
45	Bulgaria	-0.629	E
46	Turkey	-0.693	E
47	Greece	-0.747	E
48	Mexico	-0.826	E
49	India	-0.989	E
50	South Afr.	-1.207	E

Figure 2. The world map based on RC index.

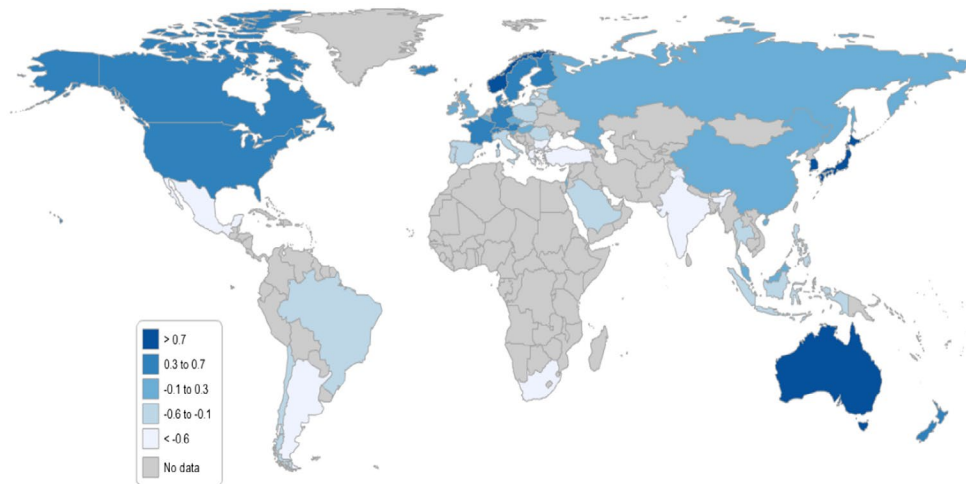
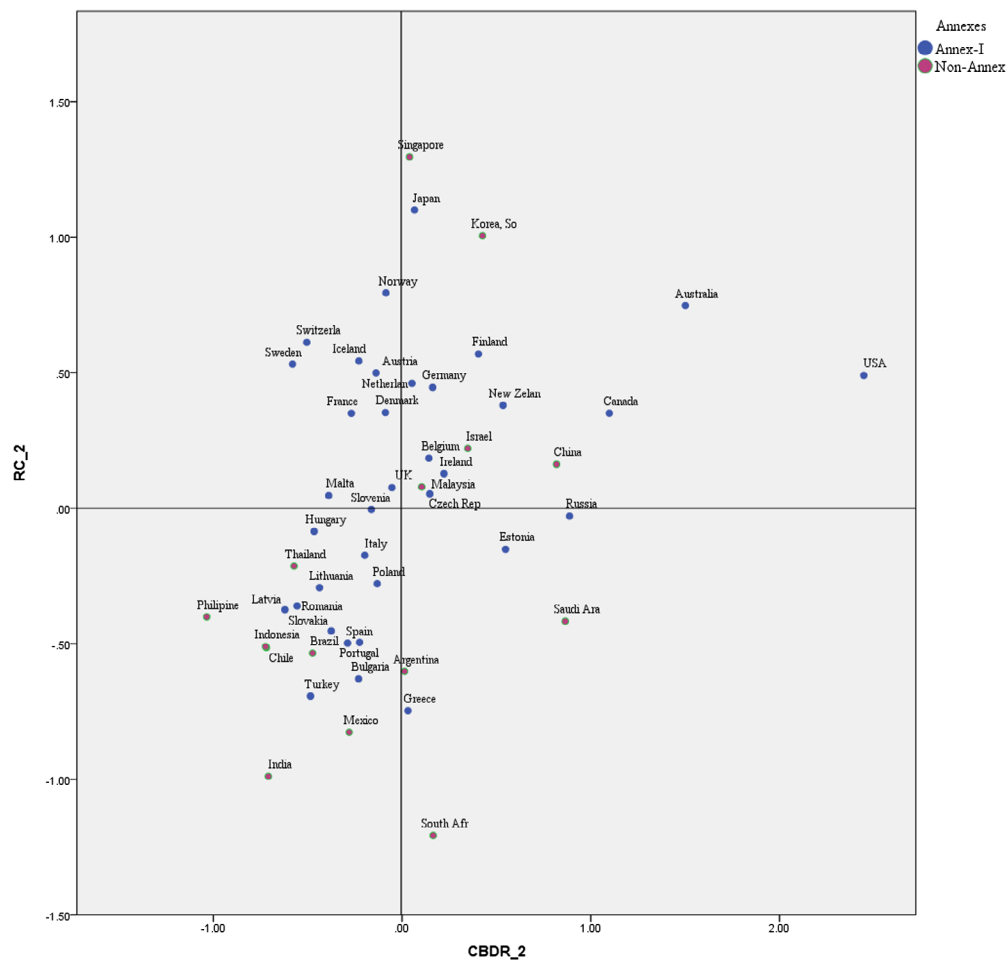


Figure 3. CBR index vs. RC index.



responsibility and low prosperity. It can be suggested that countries in this group should need external assistance to reduce their emission intensity and emission level until reaching the same prosperity level as owned by developed countries. These countries should also voluntarily make contributions in line with nationally appropriate policies. Besides, all countries in four regions should implement emission reduction activities without compromising their sustainable development needs. As a conclusion, in terms of the current classification of countries under the UNFCCC, there are no concrete differences between Annex-I and non-Annex countries. Thus, there is a need for revisiting the classification of countries in the UNFCCC.

5. Discussions

At the Conference of Parties (COP) of the UNFCCC in 2011 (COP-17), a new negotiation platform, the *Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP)*, was established in order to construct a post-2020 international climate regime. ADP opens a venue for developing countries to be involved in emissions mitigation, because the ADP's mandate encourages to include all parties without diverging as "Annex-I", "non-Annex I" (UNFCCC, 2012). It is expected that non-Annex I countries will contribute a significant emission reduction in the post-2020 climate regime through the ADP process (Aldy & Stavins, 2012). Between 2011 and 2015, climate change negotiations were discussed in order to reach a comprehensive and inclusive agreement applicable for all countries. Finally, a new legal document called Paris Agreement has been adopted in COP-21 Paris in 2015.

With important and historic moment in the ongoing process of climate negotiations (Bodansky, 2015), according to the Vienna Convention, the Paris Agreement has legal force and provides on the degree of political will behind it (Day et al., 2015). The Agreement also provides an evolution in the global climate change policy and regime in terms of shifting away from categorical binary approach (annex-1 and non-annexes in the UNFCCC) to forms of differentiation as referencing developed and developing countries (C2ES, 2015). Besides, the Agreement creates a flexible framework which covers all countries for burden sharing in emission mitigation responsibilities according to the principle of common but differentiated responsibilities and respective capabilities in light of different national circumstances. In the Agreement, though definitions and classifications of developed and developing countries are not explicitly determined, these country groups' responsibilities are differentiated in operational articles particularly in mitigation and finance (Iddri, 2015). Besides, escaping from Annex-I and non-Annex classification of the UNFCCC during preparation of the Paris Agreement, the Agreement has a paradigm shift from a closed to an open architecture (Iddri, 2015). The closed architecture which had been seen in the Kyoto Protocol, means "top-down" approaches including precise targets and fixed lists of countries (Iddri, 2015). On the other hand, the Paris Agreement is based on "bottom-up" approaches in terms of commitments types including the nationally determined contributions (NDCs), voluntarily participation of all countries, and implementation (C2ES, 2015; Iddri, 2015). In addition, there are no international enforcement mechanisms and any form of penalization for non-compliance (Day et al., 2015), it is seen that the Agreement's particular articles including transparency reflects "top-down rules". Thus, establishment process of the Agreement can be also classified as a "hybrid approach".

In order to reach long-term goals including explicit targets such as keeping the increase in the global average temperature to well below 2°C above pre-industrial levels and efforts to limit the temperature increase to 1.5°C above pre-industrial levels and climate resilience (UNFCCC, 2015), implicitly deep de-carbonization, international and regional cooperation among country parties should be enhanced. For this reason, the success of the Agreement depends on country parties ability to work, evolve, and improve, and strong policy cooperation (Iddri, 2015).

The global cooperation among all countries on the basis of equity and in accordance with their CBDR and RC has already been agreed in the UNFCCC. This study attempts to introduce and develop differentiation tools for both capabilities and responsibilities of countries in the UNFCCC and the Paris Agreement. The tools are the CBDR and RC indices. Having index scores, any country can compare its

commitment level with other countries through comparison of index values. Both index values can also be used by countries as a criterion for the determination of commitment efforts.

It is advantageous to build an innovative classification of countries that will allow more inclusive and flexible sharing of responsibilities with a dynamic nature. The differentiation of countries based on quantitative analyses with ethical concerns, particularly the equity dimensions of climate change rather than the political dimension of climate change, is perhaps one way to go. It may also help the construction of common science-based understanding. Creating a composite index involves subjective judgments regarding the selection of indicators, utilization of all data, treatment of missing data, selection of model weights, assessment of uncertainties, transparency, and identification of countries (Dobbie & Dail, 2013; Nardo et al., 2008). In this study, possible sources of uncertainty include quality of indicators, missing data, normalization method, and weighting and aggregation. All these possible sources are taken into consideration for the robustness of both CBDR and RC indices. For normalization, we employed various normalization methods, such as z-scores (standardization), min-max, and ranking. We used z-scores in our analysis to prevent significant variations in rankings of countries. In order to minimize the missing data problem, we collected data from various sources. Data used in this study are acquired from the OECD, the World Bank, the United Nations, and statistics offices of countries. This is intended to reduce the concerns on missing data and the quality of data sources. Selection of indicators for the index might be subjective particularly due to some of the social indicators in the economic capability, such as the unemployment rate. Because we conduct social capability dimension of respective capabilities in the identification of a society's resilience level, we prefer to include unemployment rate to social pillar rather than economic dimensions. The weighting and aggregations are highly subjective while creating an index. Determination of any weighting and aggregation schemes are highly challenging issues. To tackle this challenge, we utilize the principal component analysis (PCA) and use the weights from the principal components of CBDR and RC. For aggregation, additive aggregation (arithmetic mean) methods (Equations (3a) and (3b)) are applied. There is only a small difference between additive aggregation and geometric aggregation results. On the other hand, there is a significant difference between PCA and equal weights. Equal weighting is likely to lead to double counting and misinterpretation of indicators (Freudenberg, 2003), hence we applied PCA method to overcome this problem. There are different base years for selected data. For example, for cumulative greenhouse gas emissions data, there are two base years, namely, 1850 and 1990. The reason for the two different base years is related to discussions on "historical contribution" and "historical responsibility". An indicator having 1850 as base year refers to "historical contribution", while having 1990 refers to "historical responsibility". A strong correlation between "historical contribution" and "historical responsibility" might lead to biased results. The PCA method is expected to eliminate this problem.

6. Recommendation and conclusion

The Paris Agreement includes all countries for emission mitigation. This is a significant opportunity to change developing countries' emission intense production and consumption style. It is known that economic activities of major developing countries and related emissions have been increasing, and they are converging toward Western style consumption, so their exclusion from the emission mitigation responsibility is not in line with the climate justice (Harris, 2010). Until the Paris Agreement, developing countries gained a comparative advantage for being out of the quantified emission targets and hide behind their countries' low per capita income without making any contribution to global cooperation (Harris, 2010). However, after the agreement, developing countries should reduce their emissions in accordance with the principle of CBDR-RC.

After the evaluation of the various differentiation proposals, it can be concluded that the differentiation of countries for developed and developing countries should be based on quantitative analyses with dynamic review. Countries should be periodically updated so that the static position of countries can be prevented. In this manner, essential emission reduction can be globally achieved by including both developed and developing countries. Thus, Paris Agreement's classifications such as developed and developing countries cannot be based on the current annexes of the UNFCCC.

Thus, scores based on CBDR and RC indices suggest that updated annexes of the UNFCCC or new classification of countries might be one of the solution to the equity-based burden sharing. The revision should be considered not only on the mitigation commitments point of view, but also on the provision of necessary support to combat climate change.

The first recommendation is based on the ranking of countries according to the results of CBDR and RC indices. The point is that the higher a country's CBDR rank, the greater its level of responsibility. In this manner, desired and required emissions reduction can be achieved by globally including both developed and developing countries. In this case, all contributions, even very small ones, will be inside the system. This ranking system can be periodically updated.

The second alternative is based on all countries' efforts according to self-differentiation. According to the Paris Agreement, all parties' contributions are expected to combat climate change. This agreed approach can be an opportunity to include all countries' intended nationally determined contributions (INDCs) without losing their economic development. Aggregated contributions from all countries should ensure to expect an emissions reduction explained by the IPCC in the global carbon budget. CBDR and RC indices should be applied to allocate equity-based emissions reduction.

Funding

The authors received no direct funding for this research.

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Citation information

Cite this article as: Developing CBDR-RC indices for fair allocation of emission reduction responsibilities and capabilities across countries, Izzet Ari & Ramazan Sari, *Cogent Environmental Science* (2017), 3: 1420365.

Note

1. When we increase the number of components the results do not change and the rankings of the countries remain the same.

Cover image

Source: Authors.

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