A NEW APPROACH FOR THE CLASSIFICATION OF COUNTRY PARTIES IN THE UNFCCC

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ABSTRACT

A NEW APPROACH FOR THE CLASSIFICATION OF COUNTRY PARTIES IN THE UNFCCC

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The objective of this study is to create countries' composite indices for common but differentiated responsibilities and respective capabilities in order to determine fair allocation of GHG emission mitigation responsibilities between countries. All indices have been formulated by considering a country's economic, environment, social, and technical indicators. These indicators, however, are normally correlated, and their correlation may overestimate each country's responsibilities and capabilities; if the correlation of indicators is ignored as an issue, calculated index values for each country may not be used for compressions of countries. Therefore, this study suggests that is necessary to address correlation of indicators in order to determine accurate index calculations. The novelty of this study is based on selected variables with different aspects such as economic, social technical and environmental and applied techniques for creating composite indices. The data used in this study are from 50 countries that are responsible for at least eighty-one percent of global GHG emissions, including OECD countries and emerging economies. Principal Component Analysis and the Cluster Analysis techniques for index calculations and grouping of countries are employed, respectively. The results suggest that current classifications of the UNFCCC that determine the countries' responsibilities for the emission mitigation should be reconsidered. It is expected that the results contribute to the post-2020 climate agreement on emission mitigation in the context of fair burden sharing.
Keywords: CBDR & RC Principles, Principal Component Analysis, Cluster Analysis

ÖZ

BMİDÇS'YE TARAF ÜLKELERİN SINIFLANDIRILMASINDA YENİ BİR YAKLAŞIM

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Bu çalışmanın amacı, ülkeler arası sera gazı emisyonlarının azaltımı sorumluluğunun adil bir şekilde belirlenmesi için ortak fakat farklılaştırılmış sorumluluklar ve göreceli kabiliyetler endeksini oluşturmaktır. Endeksler oluşturulurken ülkelerin ekonomik, çevresel, sosyal ve teknolojik göstergeleri kullanılmıştır. Aralarında korelasyon bulunan göstergelerin kullanılması ülkelerin sorumluluk ve kabiliyetlerinin olduğundan fazla çıkmasına sebep olmaktadır. Korelasyon probleminin göz ardı edilmesi, her bir ülke için hesaplanan endeks değerlerinin ülkeleri temsil etme gücünü azaltmaktadır. Bu nedenle, değişkenler arasında korelasyonun ele alınması endeks hesaplamasında önemli bir adımdır. Bu çalışmanın özgünlüğü ekonomik, sosyal, teknolojik ve çevresel değişkenlerin ele alınması ve endeks oluşturmada kullanılan tekniklere dayanmaktadır. Bu çalışmada kullanılan veriler 50 ülkeyi kapsamakta olup, OECD ülkeleri ve büyüyen ekonomilerin de yer aldığı söz konusu ülkeler toplam sera gazı emisyonlarının en az yüzde 81'inden sorumludur. Endeks hesaplanırken Temel Bileşenler Analizi, ülkeler için gruplama yapılırken de Kümeleme Analizi kullanılmıştır. Çalışmanın sonuçları, ülkelerin sorumluluklarını belirleyen BMİDÇS'nin mevcut sınıflandırmasının gözden geçirilmesi gerektiğini tavsiye etmektedir. Bu çalışmanın sonuçlarının 2020 sonrası iklim anlaşmasında emisyon azaltımı yükünün adil bir şekilde paylaşılmasına katkı vermesi beklenmektedir.

Anahtar Kelimeler: CBDR ve RC İlkeleri, Temel Bileşenler Analizi, Kümeleme Analizi

To Ece & Kutay

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LIST OF ABBREVIATIONS

ADP	Ad hoc working group Enhanced Action of Durban Platform
BMİDÇS	Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi
CAIT	Climate Analysis Indicators Tool
CBDR	Common but Differentiated Responsibilities
CDIAC	Carbon Dioxide Information Analysis Centre
CLA	Cluster Analysis
COP	Conference of Parties
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
HDI	Human Development Index
IISD	International Institute for Sustainable Development
INDCs	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
KMO	Kaiser-Mayer-Olkin Test
LDC	Least Developed Countries
NA-I	Non-Annex I countries
NGOs	Non-governmental Organizations
NICs	Newly Industrialized Countries
OECD	Organization for Economic Co-operation and Development
PCA	Principal Component Analysis
PPP	Purchasing Power Parity
RC	Respective Capabilities
RCI	Responsibility-Capacity Index
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
WB	The World Bank
WDI	World Development Indicators
WRI	World Resource Institute

CHAPTER 1

INTRODUCTION

1.1 Background

International climate change negotiations have been continuing under the United Nations Framework Convention on Climate Change (UNFCCC). The ultimate objective of the UNFCCC is to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCCC, 1992). The UNFCCC has currently two annexes; namely Annex-I and Annex-II. Annex-I[1] countries are responsible to lead the mitigation of GHG emissions (UNFCCC, 1992). Annex-II[2] countries have additional responsibilities such as providing financial resources and technology transfer to developing countries (UNFCCC, 1992). When any country is not listed in Annex-I, it is called as non-Annex-I country. Non-Annex I countries do not have any responsibility to take binding emission reduction targets, and their efforts should contribute to emission mitigation without hindering their sustainable development pathways (Parker, Karlsson, Hjerpe, & Björn-ola Linner, 2012; Raman, 2013; Winkler, Brouns, & Kartha, 2006). However, 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 (S. Barrett, 2007; Torvanger, Bang, Kolshus, & Vevatne, 2005). However,

[1] Annex-I countries include 24 original OECD members, the European Union (EU), and 14 countries with economies in transition (EIT), Monaco, Malta, Cyprus and Liechtenstein. Annex-I includes Annex-II.

[2] Annex II countries are the 23 OECD members plus the EU.

by 2014, non-Annex I countries have not taken any quantified emission mitigation targets, according to their responsibilities and respective capabilities.

In addition to annexes of the UNFCCC, in the terms of the political economy of climate change, Annex-I countries are being recognized as developed countries and non-Annex I are considered as developing countries. However, there is neither any explicit criteria, nor definition for this matching in the UNFCCC. 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). Developed countries also argue that only global cooperation and comprehensive participation of all countries through the reduction of emissions can mitigate climate change (Baer, Kartha, Athanasiou, & Kemp-Benedict, 2008; Raman, 2013; Torvanger et al., 2005; Weisbach, 2010). However, this polarized situation and tension between developed and developing countries hinders reaching the objective of the UNFCCC, and causes to fail new climate agreement attempts such as 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),* has been established in order to construct of 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', 'developed' or 'developing' (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).

During ADP process, differentiation issues which reflect the different national circumstances across countries to ensure equitable climate change mitigation policy, have restarted to gain importance. It is expected that the differentiation linked with the equity of climate change can clarify the implication of CBDR and RC principles for assisting policy makers and negotiators. Some argue that a new differentiation approach based on the quantitative analysis of the CBDR and RC should be explored during the construction of a new agreement for post-2020 (IISD, 2013b; Raman, 2013). This linkage ultimately can provide a better implementation of the UNFCCC.

During negotiations, many countries and scholars argue that the equity in accordance with CBDR and RC should be at the core of the new agreement in order to stabilize the GHG emissions and encourage contribution of all countries (IISD, 2013b). Before ADP discussions started, there had been many approaches and differentiation proposals for the fair allocation of responsibilities. Some of the differentiation proposals will be reviewed in the next chapter.

1.2 Problem

The annexes of the UNFCCC, which was constructed in 1992 are out of date, and many non-Annex I countries have similar or even better economic and social development level which means higher responsibilities and capabilities than compared to Annex-I countries. This results in questioning of the fair allocation of responsibilities among countries (Bodansky, 2012; Heyward, 2007). 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 for common understanding that implies the revision of the current allocation of the 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 for their differentiation proposals in the literature. A revision should be based on updated data sets including different dimensions with a practical understanding of CBDR and RC principles (Karousakis et al., 2008; Ott et al., 2004). Both CBDR and RC can be used to explain countries' national circumstances in order to differentiate countries' positions and conditions in terms of any commitments. Since, both principles can have different aspects, more than one indicator or variable is needed to be considered. In this case, to better represent and compare countries' circumstances composite index can be used as a useful tool.

1.3 Objective and Scope

Differentiation can assist policy makers for fair allocations of countries' responsibilities through countries' rankings and classifications. In this study, composite indices for CBDR and RC are proposed in order to differentiate countries' positions. These indices are based on different dimensions of indicators. In addition to the commonly used variables such as economic and environmental indicators, social and technical indicators are also used in this study. Social and technical indicators were not quantitatively considered in the climate policy previously. However, these indicators have a significant role in the determination of countries' capabilities. Technical variables indicate whether countries are capable for handling their productions without hindering their economic growth, and social variables indicate public perceptions and the abilities of societies' for the mitigation policy shift. As emphasized in the latest IPCC report (Climate Change 2014), the causes and effect of climate change are varying in developed and developing countries depending on social capital such as education and interest level of society, customs and cultural dimensions for social acceptability, ability for collective action and coordination in a country, degree of equality including Gini Coefficient (Kolstad et al., 2014). Social concerns and opportunities such as education, health care, sustainable environment, social lives, etc. that are complementary to economic issues, are related to capability, level of development and quality of life (Sen, 1999). Social variables can explain to public perceptions and social transformation abilities in response to mitigation policies. National circumstances without considering social aspects and its related variables cannot be sufficient to determine countries' capabilities in the climate change. Therefore, social indicators can gain importance to determine national contributions.

The challenge with introducing and calculating indices for CBDR and RC is the determination of the appropriate indicators and methods. While creating both indices, statistical technique, such as Principles Component Analysis (PCA) and Cluster Analysis are used. PCA technique is applied to eliminate the effects of highly correlated indicators when accounting for the total variation covered by all indicators, and the CLA technique is employed to classify countries into natural groups based on the scores of CBDR and RC indices. 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).

It is expected that the results and recommendations of this study will contribute to post-2020 climate regime by introducing an analytical method for defining CBDR and RC of countries. It may also provide a flexible tool that can be used to reflect any changes in a country's position. In the next chapter, the literature on the principles of CBDR and RC, differentiation proposals and composite indices for climate change are reviewed. In Chapter Three, methods for creating composite indices are explained. Results are provided in Chapter Four. In Chapter Five, the results are discussed, and some policies are recommended. Finally, the conclusion is made in the last chapter.

CHAPTER 2

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

This chapter consists of three main parts. The first part covers two principles of the UNFCCC, the CBDR and RC which are intended to ensure justice in the allocation of emission mitigation responsibilities. In the second part differentiation proposals in the context of responsibility, capability and potential to mitigate are overviewed. In the final part, composite indices conducted by researchers, governmental institutions and non-governmental organizations (NGOs) are reviewed.

2.1 Principles of the UNFCCC

The world's and countries' circumstances have been significantly evolving since the beginning of the UNFCCC negotiation in the early 90s (Winkler & Rajamani, 2014). As mentioned earlier, classification of countries as developed/developing or Annex-I/non-Annex I is not appropriate anymore for the ultimate objective of the UNFCCC (Brunnée & Streck, 2013; Winkler & Rajamani, 2014). It is scientifically evident that the efforts of Annex-I countries will not be sufficient to halt rising of average global temperature (IPCC, 2007). During the post-2020 international climate change discussions, the first message given at the Durban Climate Conference (COP-17) in 2011 that is a new climate regime "applicable to all" for combating climate change (IISD, 2011). The future climate regime requires reinterpretation of CBDR and RC for being fair, equitable and inclusive for all countries (Winkler & Rajamani, 2014). It is argued that the more nuanced interpretation of both principles can provide a better differentiation of countries' responsibilities and capabilities rather than a simple distinction between developed and developing countries (Brunnée & Streck, 2013; Winkler & Rajamani, 2014). Therefore, both principles will play a central role during the post-2020 climate negotiations (IISD, 2013b; Müller & Mahadeva, 2013b; Raman, 2013).

2.1.1 The Concept of Equity in the Climate Change

The climate change is a tragedy of the commons (Hardin, 1968) since a country's emissions affects the whole globe, and an emission reduction by a country benefit for all countries (Kolstad et al., 2014). Besides, climate change is still a huge 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).

The language of equity has entered climate change negotiations since 1991 (Ashton & Wang, 2003). It is an important concept in international climate discussions and negotiations (Kolstad et al., 2014). The general definition of equity is an ideal that shapes people's views of what is fair, right or just (Ashton & Wang, 2003; Heyward, 2007). Equity is an issue discussed a lot while formulating the policy framework, particularly with respect to GHG emissions mitigation (Ashton & Wang, 2003; Heyward, 2007; Markandya, 2011). However the implementation of equity principles is highly problematic as there is no single solution or agreed understanding of equity (Ashton & Wang, 2003; Kolstad et al., 2014).

As Heyward (2007) presents, there are three equity principles in this frame. These are "equality", "responsibility" and "capacity" take place in Figure 2-1. Each of the equity principles, advocated by different interest groups are argued during the discussion of the fair allocation of responsibilities to address climate change (Heyward, 2007; Markandya, 2011; Mattoo & Subramanian, 2012).

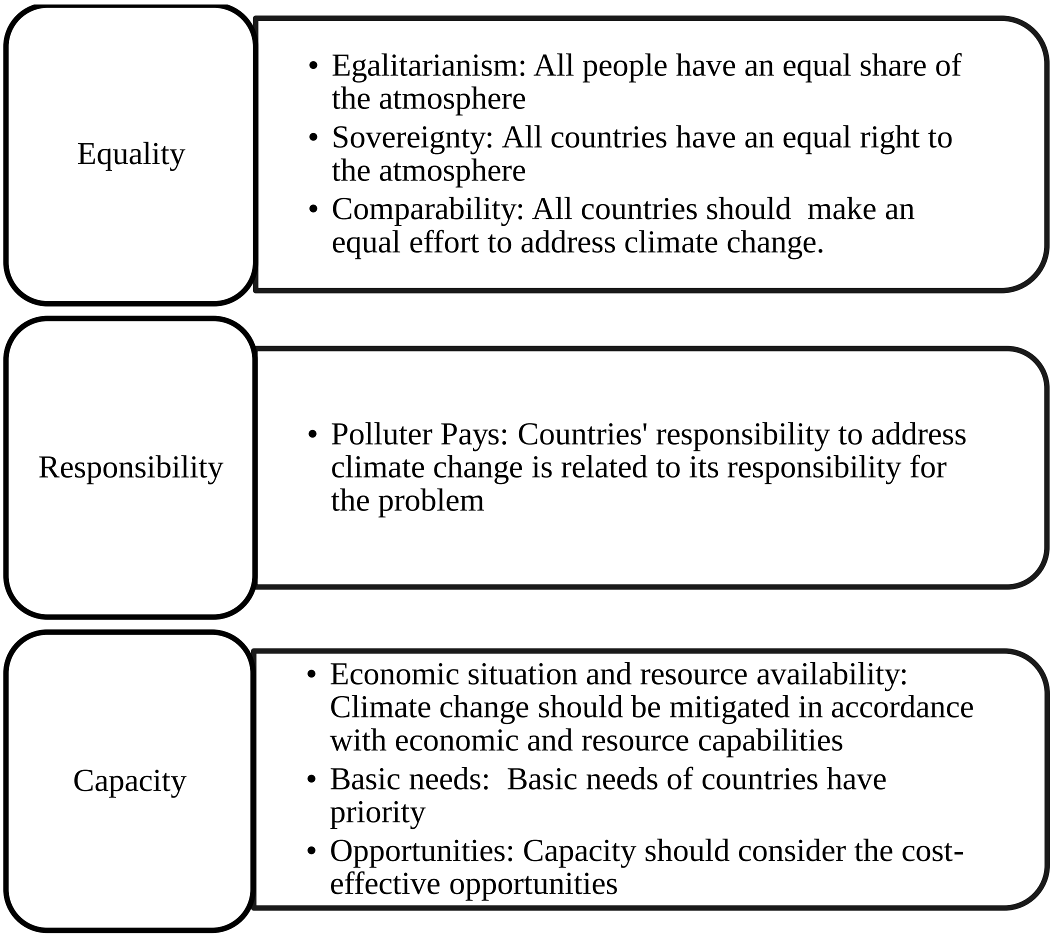

Figure 2-1: Principles of Equity in Climate Policy, (Source: Heyward, 2007)

2.1.1.1 Equality

The arguments on equality for climate change are egalitarianism, sovereignty and comparability (Heyward, 2007). The egalitarian approach is based on equality of rights over the atmosphere as a global common for all peoples, in other words, no one can own the atmosphere (Ashton & Wang, 2003; Heyward, 2007). This approach is supported by many developing countries to obtain more room for their increasing emissions, but it is criticized by developed countries (Heyward, 2007). Developing countries who have less per capita emission than developed countries argue that their per capita emissions might have to increase in order to reach a better economic development level (Agarwal & Narain, 1991).

The sovereignty approach which is based on equality of rights for all countries takes into account current emission levels (Heyward, 2007). This approach restricts the economic growth of developing countries as developing countries comprise more than half of global emissions (Heyward, 2007; WRI, 2014). Developed countries support this approach, while developing countries are against it (Heyward, 2007).

The comparability approach, which is based on ‘similar countries should take a similar degree of effort’ (Ashton & Wang, 2003), is supported by developed countries to prevent a ‘free rider’ problem and it is criticized and rejected by developing countries because of their lower contribution to mitigating efforts (Heyward, 2007).

2.1.1.2 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 responsibility have been made (Füssel, 2010), there is no consensus on the common understanding of responsibility concept (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 & Fuglestvedt, 2008). Polluter pays principle is based on the ethical notion that *thou shalt not harm others* or at least not harm others ‘knowingly’ and compensation of harms (Mattoo & Subramanian, 2012). In other words, any polluter who is conscious about his/her caused the damage should have greater responsibility than others who are not doing so (Ashton & Wang, 2003).

Historical emissions of countries have caused the increase in global average temperature (Müller, Höhne, & Ellermann, 2009). The recognizing of any activities in the context of historical responsibilities requires an awareness of the consequences of these activities (Müller et al., 2009). In the literature, historical responsibility is emphasized by Brazilian Proposal in 1997 for calculation of the impacts of past emissions for allocating the emission mitigation targets, according to polluter pays principle (Rive, Torvanger, & Fuglestvedt, 2006). In this proposal, historical responsibility starts with the industrial revolution and it proposes that future emissions can be allocated with inversely proportional to countries' historical responsibilities (Ashton & Wang, 2003; Mattoo & Subramanian, 2012). During the climate negotiation, for post-2020, developing countries are recalling historical responsibility for equity framework (IISD, 2013b). They are also advocating the Brazilian Proposals on historical responsibilities and are inviting the IPCC and countries to estimate historical emissions and the contribution of developed countries' to the temperature increase (IISD, 2013b).

However, there are some concerns related to historical responsibility. The *first* is related to the attribution of blaming that countries without knowing about the results of GHG emissions is arguable (Heyward, 2007; Müller et al., 2009). There is a correct attribution problem in historical responsibilities in terms of whether countries that were unaware of the consequences of their activities are responsible or not (Caney, 2010; Shue, 2010). This argument is directly linked to the selection of the base year. For example, some of the scholars argue that historical responsibilities should start in 1990 according to the scientific conclusion of the first report of the IPCC (Ashton & Wang, 2003; Baer et al., 2008; Michel G.J. den Elzen et al., 2005), while the calculation of causal/historical contribution can start at 1750, 1850, 1950, and 1990 for different perspectives (Rive & Fuglestvedt, 2008). The *second* debate is related to the ethicality of punishing current and future generations for historical emissions (Markandya, 2011). However the relation of cause-effect in climate change is uncertain and difficult to quantify. In fact, compensation for any damage does not solve the problem by itself (Ashton & Wang, 2003). Additionally, the polluter pays principle deals with emissions for a certain period of time (Mattoo & Subramanian, 2012), but responsibility can range in different timeframes such as: historical, current and future. Due to continuity of the climate change problem with a differing degree of contributions (Heyward, 2007) in terms of historical emissions, certain polluting actors might no longer exist, raising the question of who now should be responsible for compensation. If a country emits GHG to the atmosphere currently, they should recover this pollution (Caney 2010) , but in case of the past emissions it is not fair to hold the current generation is responsible for past pollution (Caney, 2010; Shue, 2010). The *third* and last debate on the start year of the historical responsibility. Criticism from developing countries is related to the fact that most of the developed countries have already departed from the energy intense economy, so the 1990 point does not truly represent the historical responsibility (Baer et al., 2008; Cao, 2008; Wei et al., 2013). The counter argument points out that economic and social development in developed countries also has provided many benefits to developing countries (Shue, 2010). For instance, development in the area of medicines and technologies in developed countries also raised the standard of living in developing countries (Shue, 2010).

For these reasons, there are many objections to features of historic responsibility in climate change negotiations. Taking into account these objections, two different years, namely 1850 and 1990 are selected while defining responsibility in this study. Both years are presented as cumulative GHG or CO_2 emissions since 1850 or 1990.

2.1.1.3 Capacity

Generally, capacity is highly related to the welfare of societies, technology, institutions, skills, information and opportunities. Heyward (2007) defines the capacity in the climate scholar under the frame of economic situations, basic needs and opportunities. The *first* point argues that the economic situation and resource availability have a big role to combat climate change, and developed countries have higher economic, institutional and human capacity than developing countries. The *second* point advocates that the basic needs of countries' are not similar depending on the eradication of poverty, and economic and social development (Heyward, 2007). For instance, economic growth and the eradication of poverty can be more important than the mitigation of emissions. In the *third* point, opportunities can be defined in the context of the capability for transition to less emission intense economy through reducing the emissions in the overall economy (Heyward, 2007). In this concern, some countries which have conventional energy intense technologies and economic structure, have opportunities to choose new and low carbon technologies.

When all the capacity points are merged with an equity perspective of climate change, it is expected that the more prosperous countries have more capacity to address the problem, so developed countries have a comparative advantage over the developing countries, and have capabilities to address the problem (Ashton & Wang, 2003). Any country with a high capacity should contribute more than other countries with less capacity. The greater the wealth the higher the contribution to the problem will be.

2.1.2 Principles and Annexes of the UNFCCC

Generally, the UNFCCC is accepted as a well prepared international legal agreement. Its articles and related provisions provide a worthy guidance in order to solve global climate change problems. The required actions in the UNFCCC are disturbed according to countries' national circumstances and responsibilities of countries are differentiated between developed and developing countries according to their capabilities. In the context of the preamble, principles, objective and commitments of the UNFCCC, there are so many matters concerning the differentiated responsibilities to combat climate change. However, there is no explicit definition of developed and developing countries and the meaning of "differentiated responsibilities" in the UNFCCC. Besides, the existing annexes of the UNFCCC, which does not reflect today's countries' capabilities and responsibilities, does not provide sufficient flexibilities to the rearrangement of countries' position in the annexes. There are two annexes namely Annex-I and Annex-II in the UNFCCC (Table 2-1). In Annex-I, there are 43 parties which applies to the industrialized countries including 23 OECD members by 1992, the European Union, and 14 countries with economies in transition. According to the UNFCCC, Annex-I countries should lead to emission reduction and communicate their mitigation policies and actions to the UNFCCC's Secretariat periodically. These countries' emission reduction activities and GHG emission inventories are published in the UNFCCC Secretariat with a certain period of time.

In Annex-II, there are 24 parties which are addressed to the 23 OECD members, plus the EU. Annex-II countries, in addition to the leading role in emission mitigation, have responsibility of providing new and additional financial resources, technology transfer and capacity building to developing countries (UNFCCC, 1992). Annex-I includes Annex-II (Figure 2-2).

Table 2-1: Annexes of the UNFCCC

Annex-I	**Annex-II**
Australia	Australia
Austria	Austria
Belarus[3a]	Belgium
Belgium	Canada
Bulgaria[a]	Denmark
Canada	European Economic Community
Croatia[a]	Finland
Cyprus	France
Czech Republic[a]	Germany
Denmark	Greece
European Economic Community	Iceland
Estonia[a]	Ireland
Finland	Italy
France	Japan
Germany	Luxembourg
Greece	Netherlands
Hungary[a]	New Zealand
Iceland	Norway
Ireland	Portugal
Italy	Spain
Japan	Sweden
Latvia[a]	Switzerland
Liechtenstein	United Kingdom
Lithuania[a]	United States of America
Luxembourg	
Malta	
Monaco	
Netherlands	
New Zealand	
Norway	
Poland[a]	
Portugal	
Romania[a]	
Russian Federation[a]	
Slovakia[a]	
Slovenia[a]	
Spain	
Sweden	
Switzerland	
Turkey[4]	
Ukraine[a]	
United Kingdom	
United States of America	

[3] a: Countries that are undergoing the process of transition to a market economy
[4] Turkey was deleted from Annex II by an amendment that entered into force 28 June 2002, pursuant to decision 26/CP.7 adopted at COP7

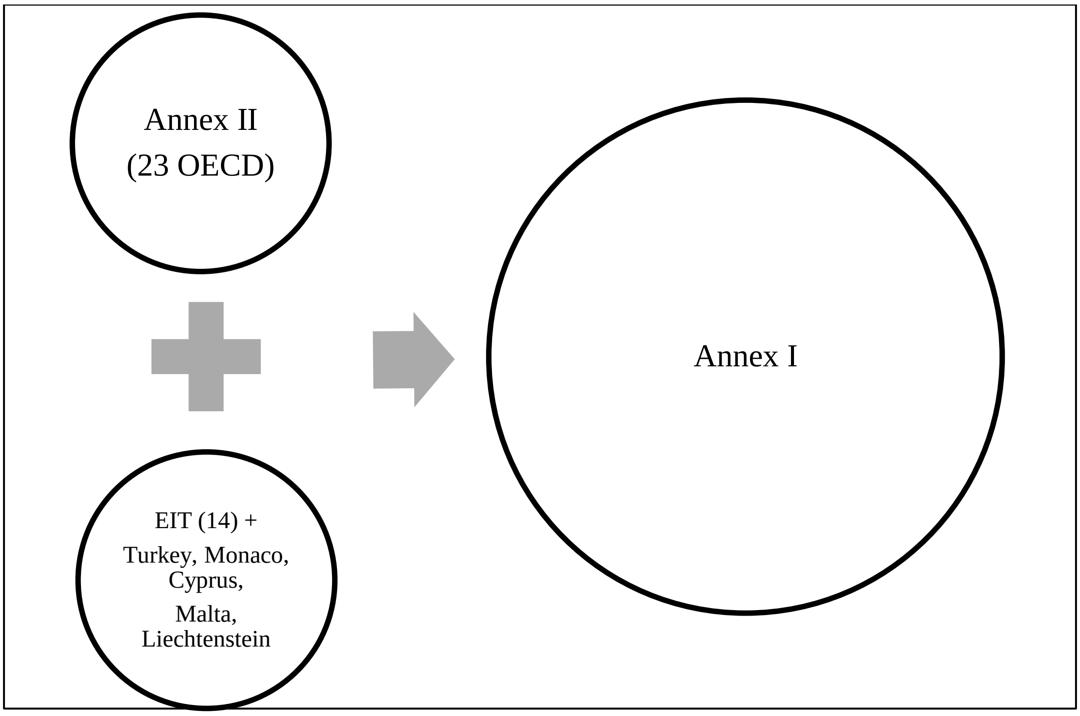

Figure 2-2: Annexes of the UNFCCC

When any country is not listed in Annex-I, it is called as non-Annex I. The general position of non-Annex I countries is to keep their high economic growth, reduce poverty and take action in the climate regime according to the principle of CBDR (Parker et al., 2012; Raman, 2013). These countries do not have any quantitative obligation for emissions reduction, and they are receivers of finance and technology transfer and eligible for market-based mechanisms such as Clean Development Mechanism (CDM) as a host country (UNFCCC, 2013). Non-Annex I countries do not want to take the sorts of commitments as of Annex-I (Baer et al., 2008). But developed countries often emphasize the need of developing countries' efforts, particularly emerging economies and newly industrialized countries for global co-operation (Weisbach, 2010). This the dichotomous classification of the UNFCCC as Annex-I/non-Annex I and this tension between developed and developing countries have had a negative effect, such as lack of progress in the climate negotiation (Aldy & Stavins, 2012).

There are many major economies not listed in the Annex-I. Table 2-2 lists some of the non-Annex I countries. Although many of non-Annex I countries, namely China, Brazil, South Korea, Mexico, India, Indonesia, etc. have significant amount of GHG emissions, they have not any legally binding responsibility to reduce their emissions.

Table 2-2: Some of the non-Annex I Countries

Countries		
China	Indonesia	Chile
Brazil	Saudi Arabia	Malaysia
Mexico	South Africa	Qatar
India	The Philippines	Egypt
South Korea	Iran	Nigeria
Argentina	Israel	Singapore
Azerbaijan	Turkmenistan	Thailand

As mentioned earlier, efforts only from Annex-I countries will not be sufficient to stop global temperature increase. On the other hand, the expected emission reduction from developing countries' commitments have not been taken as planned earlier. For instance, one of the largest emitters, the USA, has not ratified the Kyoto Protocol and this has led to the weakening of the ultimate objective of the UNFCCC (Aldy & Stavins, 2012). The USA argues that if developing countries do not reduce their emissions, any efforts only from developed countries will not be sufficient to reach the objective of the UNFCCC. Nonetheless, developing countries strongly disagree with an agreement that includes commitments addressing their emission mitigation (Bodansky, 2010). Developing countries do not want to mitigate emissions and contribute to climate finance, because they think that they are not responsible for the current climatic problems within the principle of historical responsibilities (Weisbach, 2010). Developing countries assume that any legally binding targets will cause to loss of their development priorities (Baer et al., 2008), so they consider climate protection as an obstacle to reach their development needs (Aldy & Stavins, 2012). Such countries argue that the allocation of responsibilities should be limited to developed countries for emission mitigation and financial contribution commitments (Parker et al., 2012). Besides, developing countries have the majority of the seats in the UNFCCC, so these countries have comparative advantage over Annex-I parties during the negotiations and decision making process. Thus, the responsibilities between developed and developing countries were not allocated fairly on the basis of equity, CBDR and RC. Therefore, the divergence between developed and developing countries is also an obstacle to reach the objective of the UNFCCC.

There is a need for eliminating the polarized positions of countries in the UNFCC through stabilization of GHG concentration. At the beginning of the preparation of the UNFCCC (Table 2-3), the establishment of annexes might not be desired to be an obstacle for effective emission reductions, but this issue is still consuming time between developed and developing countries to reach an agreement. The Article 2 of the UNFCCC requires further related legal instrument to stabilize the GHG concentrations in the atmosphere in order to protect ecosystems. Therefore, the implementation protocol of the UNFCCC, namely Kyoto Protocol, entered into force in 2005. However, insufficient efforts from Annex-I countries and the second commitment period of the Kyoto Protocol required a new negotiation framework called post-2012 climate regime. Between 2007 and 2009, the structure, allocation of responsibilities, the development needs of developing countries through combatting climate change were discussed and negotiated in the scope of post-2012. Because of the highly polarized position of developed and developing countries in the allocation of responsibilities caused to fail establishment of a new legal document during the Copenhagen Climate Conference in 2009. In other words, the post-2012 climate regime collapsed. The need for all parties’ contribution and urgency for actions were underlined during the Durban Climate Conference (COP-17), so Durban Platform for Enhanced Action (ADP) was established in 2011.

Table 2-3: Important Steps of International Responses to Climate Change

Year	Action
1990	IPCC’s first assessment report released. The negotiation of climate change framework convention begin
1992	At the Earth Summit in Rio, the UNFCCC is opened for signature
1994	UNFCCC enters into force.
1997	Kyoto Protocol formally adopted in December at COP-3
2005	Entry into force of the Kyoto Protocol.
2007	The Bali Road Map accepted and post-2012 negotiations begin
2009	Copenhagen Climate Conference (Copenhagen Failure)
2011	Establishment of the Durban Platform for Enhanced Action (ADP)
2013	Decisions on further advancing the Durban Platform
2014	Call for Actions for post -2020 in Lima COP 20

Source: (UNFCCC, 2014b)

The novelty of ADP’s mandate is based on bottom-up approach by including all parties’ efforts. ADP’s mandate does not only eliminate developed and developing countries divergence, but also do not stick to Annexes of the UNFCCC. It is believed that even a small contribution from a country, without compromising their development needs, can assist to reach the ultimate objective of the UNFCCC. In line with this, ADP’s mandate has been recalled, and further arrangements have been formulated at COP-19 in 2013. This formulation is framed within Intended Nationally Determined Contributions (INDCs). At COP-20 in 2014, the Lima Call for Climate Action decisions, it is noted that there is a significant gap between current emission efforts and required actions holding the rise of global temperature below 2 °C above pre-industrial levels (UNFCCC, 2014c). In this decision, it is also decided that a new protocol for post-2020 climate regime will be applicable to all Parties contributions in the context of INDCs. The differentiation of commitments and contributions in the light of national circumstances, the principle of CBDR and RC are reiterated for post-2020 climate agreement in the Lima Call for Action decisions the Article 3. The discussion on the INDCs has been progressed in COP-20 in December 2014. The decision is parallel with the ADP mandate in terms of not mentioning Annex-I and non-Annex I countries. Generally, Lima decisions are reiterating the ultimate objective of ADP successfully. Therefore, the distinction between political north and south has been broken. Consequently, this can help to accept a new opportunity to break the country's annex-based positions. All countries will contribute emission mitigation efforts according to national circumstances. Therefore, the representation of the countries' national circumstances through quantification of related indicators gains a significant importance for construction of post-2020 climate agreements. As acknowledged in the Lima decisions, CBDR and RC are mainly required for quantification to explain countries circumstances and comparing their efforts. The implication of both principles, in order to assist all countries for explaining their INDCs and comparing all countries' emission reduction contributions with other countries, are urgently needed. Therefore, quantified implication of CBDR and RC can be very useful tool for policy makers and negotiators.

2.1.2.1 Common but Differentiated Responsibilities (CBDR)

The principle of CBDR, declared in UN Conference on Environment and Development in 1992, is one of the main principles of the UNFCCC (EoE, 2013; UNEP, 2013). The CBDR has two features. One is "common", that refers to the common problem of Earth, and recalls the duty of all countries for combatting climate change; the other is "differentiated responsibility", which is concerned with countries' national circumstances such as socio-economic conditions and the institutional capacity of the country during the equitable allocation of responsibilities (EoE, 2013). In the preamble, the UNFCCC calls for the cooperation by all countries in accordance with their CBDR principle. In the Article 3 of the UNFCCC:

> The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their **common** [my emphasis] but **differentiated responsibilities** [my emphasis] and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.
>
> (Art. 3.1 of the UNFCCC 1992)

According to the Article 3, the main responsibility for emission mitigation has been given to the developed countries. However, the UNFCCC does not suggest any explicit criteria of who are 'developed countries', and how their responsibilities are differentiated from those of developed ones (Stephenson & Boston, 2010). Besides, up to date, there is no study on "quantitatively operationalizing" the CBDR for climate change negotiations. While Annex-I parties are recognized for main responsible group for the emission mitigation and Annex-II parties are recognized for technology transfer and finance to assist developing countries (UNFCCC, 1992), that classification has not been updated, and many countries have made considerable progress in the economic size and prosperity since 1992 (WDI, 2013).

In the climate change negotiations, developing countries' negotiating groups, particularly G-77 / China, African and Arab Groups, are happy with the existence of the principle of CBDR (IISD, 2013a; Raman, 2013; UNCSD, 2012). They emphasize this principle in their statements, particularly when all countries' responsibilities under discussion (IISD, 2012). They argue that they are not responsible for the current climatic problems historically (Weisbach, 2010), so the responsibilities should be allocated among developed countries for emission mitigation and supplying financial resources according to CBDR (Parker et al., 2012). On the other hand, developed countries disagree to categorize countries as Annex-I and Non-Annex I or developed / developing country, so they argue for a dynamic approach in order to provide fair and ambitious mitigation efforts (Raman, 2013). Because it might not be possible to reach the ultimate objective of the UNFCCC without active participation of developing countries (Baer et al., 2008; Torvanger et al., 2005). They argue that developing countries should take responsibility in accordance with principles of CBDR and RC (S. Barrett, 2007; Torvanger et al., 2005).

The establishment of ADP in 2011 without any divergence among countries for establishing post-2020 climate agreement could be a significant opportunity to involve all countries, particularly developing countries in the mitigation and finance efforts on climate change (UNFCCC, 2012). Many climate policy scholars have acknowledged this condition as the fundamental change for the post-2020 climate regime (Aldy & Stavins, 2012). On the other side, some scholars (GDR, 2013b; Müller & Mahadeva, 2013a), and reflections from non-Annex I country parties at negotiation of post-2020 climate agreement (IISD, 2012, 2013a; Raman, 2013), show that CBDR seems to continue their impacts on new climate regime, because developing countries insist on existence of the CBDR in any new legal instrument for post-2020 climate regime

(IISD, 2012; Raman, 2013). Therefore it can be concluded that the true implications of the CBDR on climate policy will be experienced during the work of ADP.

2.1.2.2 Respective Capabilities

Similar to CBDR, RC exists in the preamble and the Articles 3 of the UNFCCC. During the negotiation under the ADP, for instance, there are many countries' and NGOs' statements or interventions stressing the relation between commitments and RC (IISD, 2012; Müller & Mahadeva, 2013b). The stresses were on the impossibility of success in the climate change negotiations without considering 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). Capability is not only the focus on per capita GDP and per capita emission; but also other dimensions, including social, economic, technological and institutional indicators should be considered (Winkler, H., Baumert, K., Blanchard, O., Burch, S., & Robinson, 2007).

In terms of economic capability, Müller and Mahadeva (2013a) emphasize the operationalization of Article 3.1 of the UNFCCC – differentiation of responsibilities according to respective capabilities. They 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. They criticize the determination of ability by using GDP or per capita GDP only; because they believe that this might not give a fair allocation of responsibilities. For instance, some countries such as India and Japan have almost same economic size (GDP) or some other countries Switzerland and the USA have close prosperity level (GDP per capita), but it cannot be said that they are similar in terms of burden sharing for emission reduction. Müller and Mahadeva (2013a) modify GDP in terms of relative prosperity levels, which is determined by the taxable income (income tax liability), and obtain the gross taxable income based on the general ability to pay (gross capability measures). Then, they deduct the cost of eradication of poverty from this gross capability measure, and derive the net ability to pay which is called the 'Oxford Capability Measure' (OCM). They also propose and calculate the OCM for all countries as a measure of RC in order to differentiate cost. All positive[5] OCM measures are calculated for countries, so the Oxford Capability Index obtained for the cost shares. They also use only positive OCM because some poor countries with negative OCM cannot concern climate change over the poverty eradication. Additionally, the Oxford Approach gives a suggestion to operationalization of RC together with the other approaches like historic responsibilities to differentiate national circumstances (GDR, 2013a; Müller & Mahadeva, 2013b). However, they only handle the economic dimension of the RC. The technological and social dimensions should also be integrated into economic dimensions holistically, because countries' technological level may hinder the economic growth and/or public perception may prevent the necessary social support during the implementation of environmental policies.

2.2 Overview of the Differentiation Proposals

In the climate policy literature, there are many differentiation proposals focusing on fair allocation of emission mitigation responsibilities (Bodansky et al., 2004; Gupta et al., 2007; Stavins et al., 2014). In the context of this study, selected differentiation proposals consider determination of responsibility level based on qualitative and quantitative national indicators. Overviewed differentiation proposals are seeking to reclassification of country parties in the UNFCCC. These proposals are "the South-North Dialogue" (Ott et al., 2004), "the Graduation and Deepening" (Michaelowa, Butzengeiger, & Jung, 2005), "Greenhouse Development Rights" (Baer et al., 2008), "Historical Responsibilities" (UNFCCC, 1997), "the Sao Paulo Proposal" (Basic, 2007), "Contract and Convergence" (GCI, 1995) and "the Concentric Differentiation" (UNFCCC, 2014a). The common concern in these proposals is to suggest that countries emission reduction commitments or contributions should be based on each country's responsibility and capability (Bodansky et al., 2004; Deleuil, 2012; Gupta et al., 2007).

2.2.1 The South-North Dialogue

The South-North Dialogue aims to address the climate change problem in a comprehensive manner for both developed and developing countries (Ott et al., 2004).

[5] Countries with negative OCM are exempted from having to contribute to costs, in the same way in which earning less than ones tax allowances entails an exemption from paying income tax (Müller & Mahadeva, 2013b)

This proposal's differentiation is based on responsibility (cumulative carbon emissions per capita between 1990 and 2000), capability (per capita GDP and HDI) and mitigation potential (emission intensity, per capita emission and emission growth rate) (Bodansky et al., 2004; Karousakis et al., 2008; Ott et al., 2004). Linearly combination of these three indicators with equal weighting creates a composite index. According to results of this index scores, countries are classified as Annex-II of the UNFCCC, Annex-I but not in Annex-II in the UNFCCC, Newly Industrialized Countries (NICs) such as South Korea, Saudi Arabia, China, Brazil, Mexico, other developing countries and Least Developed Countries (LDCs) for the differentiation of emission mitigation (Karousakis et al., 2008; Ott et al., 2004). Therefore, four country groups based on the mean and standard deviation of countries' index scores are classified as summarized in Table 2-4 (Michel G.J: den Elzen, Höhne, Brouns, Winkler, & Ott, 2007). The meaning of this classification is based on mixture of quantitative and qualitative threshold of each country's national circumstances for emission reduction. With this classification approach, the South – North Dialogue Proposal is classifying countries according to stage based burden sharing in the international climate change regime (Gupta et al., 2007).

Table 2-4: Grouping of Countries in accordance with the South-North Dialogue

Groups	Rule
First	Above the mean plus standard deviation. If any country is in Annex-I, it keeps target as usual. If not, it takes commitment as Annex-I
Second	Between mean plus standard deviation and mean. If any country is in Annex-I, it keeps target as usual. If any country is in newly industrialized countries (NICs), it takes commitment as Annex-I.
Third	Between mean and mean minus standard deviation. If any country is in Annex-I, it keeps target as usual. If any country is in NICs, it takes limitation commitment that would be conditional
Fourth	Below mean minus standard deviation. No quantified emission reduction targets

Source: (Ott et al., 2004)

However, this proposal did not consider GHG emissions prior to 1990 level. Without considering emissions since industrial revolution in other words not choosing start year as 1850 affects countries responsibility level (Wei et al., 2013). Many developed countries economic growth rate and associated emissions were remarkable higher than developing countries between 1850 and 1990. Therefore, historical GHG emissions and their impacts on current global climate problem should be considered while determination of responsibility level.

2.2.2 The Sao Paulo Proposal

The Sao Paulo Proposal encourages developing countries to take emission mitigation actions flexibly (Basic, 2007). According to this proposal, Annex-I countries are responsible for the absolute targets. For non-Annex I countries, there is a threshold determining the responsibility and capacity based on mixes of criteria such as per capita GHG, per capita cumulative GHG emissions since 1990 and per capita GDP (Basic, 2007; Karousakis et al., 2008). If the values for any country is higher than any Annex-I countries, that country is classified as an eligible country for quantified emission reduction, and/or listed in Annex-I (Karousakis et al., 2008). In accordance with this threshold rule, there are three groups. Group-1 comprises Annex-I countries. Group-2 comprises non-Annex I countries whose per capita GDP and per capita GHG emissions are higher than those of Annex-I. Group-3 is based on ones having values lower than that of Annex-I country's indicators. Any country in Group-3 is not expected to adopt quantified emission reduction commitments. With this methodology, the Sao Paulo Proposals has been acknowledged in the context of strong multilateralism in order to ensure countries' ambitious emission reduction targets (Stavins et al., 2014). However, this proposal did not include historical (start year as 1850) cumulative emissions level. Thus, this proposal should concern stocked emissions level in the atmosphere for equity based burden sharing responsibility.

2.2.3 Greenhouse Development Rights

Greenhouse Development Rights (GDRs) establishes a responsibility-capacity index (RCI) with a development threshold to provide a tool for the allocation of responsibilities for emission mitigation (Baer et al., 2008). The proposal defines responsibility as cumulative CO_2 emissions from fossil-fuel combustion (1990–2010) excluding emissions below the corresponded population of under development threshold. It also defines the capability as per capita GDP above corresponded population of the development threshold. The RCI share of each country can be calculated in GDR calculator (GDR, 2013a). Some of the parameters of this calculator are based on development threshold (US$ 7,500), which gives the idea of basic needs, and cumulative per capita emission since 1990 (GDR, 2013a). The emissions below the corresponding development threshold are excluded from the calculation of RCI. The proposal suggests that both developed and developing countries' populations exceeding the development threshold should address mitigation according to their share in global RCI (Cao, 2010). In other words, the share of RCI will be directly proportional to countries' emission mitigation commitments. GDR considers high income and high emission individuals for emission mitigation in any country in line with its share of RCI, except the least developed countries (LDC) (Wei et al., 2013). The novelty of the GDR is based on the economically unequal individuals in each country and concerning the development threshold for their responsibilities in the context of CBDR and RC (Baer et al., 2008; Wei et al., 2013).

Although the GDR focuses on wealthy people and their contribution to climate change, it is difficult to deal with this proposal on climate change negotiations (Müller & Mahadeva, 2013b). This is because it needs intra-national differentiation among low income groups and high income groups. This method might not comply with sovereignty principles, and all countries want to negotiate their positions in a unified manner. This proposal also did not consider cumulative GHG emission since industrial revolution, so it is difficult to truly reflect countries real responsibilities (Wei et al., 2013)

2.2.4 Graduation and Deepening

This proposal is based on two equity principles of differentiation: the polluter pays (per capita emissions) and capabilities or ability to pay (per capita GDP) (Michaelowa, Butzengeiger, & Jung, 2003; Michaelowa et al., 2005). In this proposal transition or graduation of any country is based on proposed indicators of countries (Gupta et al., 2007). To differentiate non-Annex I countries, there are four emission reduction target groups based on a graduation index (GI) (Bodansky et al., 2004). This index has been further categorized according to three thresholds: the average GI score of Annex-B (one of the Annex of the Kyoto Protocol), the lowest GI score of Annex-II, and the lowest GI score of Annex-B (Karousakis et al., 2008). Besides these, there is an institutional criteria. For example, members of the EU or OECD directly classified as Annex-B countries (Bodansky et al., 2004).

1. Developing countries with greater GI than that of Annex-B average: adopt mitigation target as the average of Annex-B countries
2. Developing countries whose GI are below the Annex-B average, but above that of the lowest Annex-II country: adopt target equivalents to the same amount as the least of Annex-B
3. Developing countries whose GI are below the lowest Annex-II country, but above that of the lowest Annex-B country: adopt stabilization targets.
4. Developing countries with smaller GI than that of the lowest Annex-B country: do not have to take any binding target, it is voluntary to adopt any target.

According to this rule, some non-Annex I countries such as South Korea and Mexico should be in Target Group 1 because of being OECD member states. This proposal classifies countries' type of emission reduction responsibilities according to staged based systems in the frame of international burden sharing (Gupta et al., 2007). However, used indicators such as per capita GDP and per capita GHG emissions only measure emission intensity and general overall prosperity of a country. Current and historical emission levels were not taken into account in this proposal. Besides, per capita GDP should not be only one criterion to measure capability level of country. It is difficult to say true capability level of any country is reflected in Gradation and Deepening proposal. More economic and social development indicators should be used to determine for capability.

2.2.5 Historical Responsibilities

Historical Responsibilities is known as the 'Brazilian Proposal' in climate policy literature (Rive et al., 2006). It is based on the 'polluter pays' principle and cumulative emission contribution by countries since the industrial revolution (Heyward, 2007; UNFCCC, 1997). This proposal based on the argument that emissions reduction should be committed and differentiated among Annex-I countries due to the fact that the majority of past emissions originated from these countries (Michel G. J. den Elzen et al., 1999; Müller et al., 2009). There is still no consensus among countries on the start year of the historical responsibilities. Annex-I countries argue that the start year of historical responsibility should be 1990. Because they claim that the evidence of climate change, its reasons and causes were not been known well before 1990, so their emissions before this year cannot be included to the calculation of historical responsibilities.

There are two main disadvantages to this proposal. The first disadvantage is related to exclusion of non-Annex I countries' burden sharing responsibility. Emission level and growth rate of non-Annex I countries are higher than Annex-I, so non-Annex I countries' emission contribution should be included. Lack of consideration of necessary regulations and instruments for implication of emission reductions for developing countries is the second disadvantage (Wei et al., 2013). Therefore, Historical Responsibility proposal should consider both different starting year and necessary tool for classification of countries.

2.2.6 Contraction and Convergence

Contraction and convergence model has been proposed by the Global Commons Institute (GCI) in the early 90s. The aim of the proposal is to sustain equity in the climate change which has been destructed due to the current economic structure of the world causing the GHG emissions (GCI, 1995). The model is proposed long term contraction in the amount of the GHG emissions to stabilize the concentration of GHG emissions consistent with the findings of the IPCC's report. The model is also proposed to convergence in the per capita emissions which is expected to equal among all countries for an agreed year in the future (GCI, 1995). All these suggestions in the model are based on the principles of precaution and equity in the UNFCCC. According to model, it is expected to keep a carbon budget at a constant amount and reach to linear convergence as equal per capita emission by 2050. The model also ensures to the conservation of the global common system on the basis of all peoples rights to an equal share of the atmosphere. In these perspectives, this proposal is based on allocation of emission allowances for all countries according to contraction level of per capita emissions (Gupta et al., 2007).

2.2.7 The Concentric Differentiation

The Concentric Differentiation proposal has been made by the Brazilian Government in 2014 in order to sustain effective participation of all countries in the new agreement which is expected to be completed at the end of 2015. The main argument of this proposal is to operationalize the principles of CBDR and RC into the post-2020 agreement through differentiation of countries' intended nationally determined contributions (INDCs) (UNFCCC, 2014a). This proposal emphasizes that new climate regime should be fully in line with the principles of the UNFCCC, and should give responsibility to not only developed countries but also developing ones. Although developed countries are expected to lead emission mitigation, developing countries also reduce their emissions consistent with their national circumstances based on CBDR and RC. It means that each country defines its ambitious emission reduction targets itself.

The concentric differentiation needs all countries' efforts, taking into account of each country's priority such as economic and social development, poverty eradication. According to the proposal, all the needs both for country's priorities and combatting climate change are based on CBDR and RC through updating countries' progress in a determined period of time. Considering all countries different levels of development, there are five main options for countries' conditions. The *first* one is an absolute emission reduction target according to a base year in the past. The *second* one is emission reduction target relative to a business as usual projection. The *third* is an emission limitation with regard to emission intensity in the economy as a change of emission in per unit GDP. The *fourth* is an emission reduction target in terms of per capita emissions. The *fifth* and the last one is non-economy wide actions. This proposal suggests that Annex-I countries should follow the first option. Least developed countries should follow the least difficult option which is option five. All other parties (non-Annex I, emerging economies and other developing countries) except the least developed countries and Annex-I should be expected to take emission reduction targets options between the first and fourth one (UNFCCC, 2014a). The proposal suggests that emission reduction should be encouraged through providing support to developing countries and dissemination of market mechanism such as emission trading system among all parties.

Table 2-5: The Comparison of Differentiation Proposals

Approaches	Aim	Scope	Equity-related Argument/Principle	Differentiation Groups	Proposed by
South-North Dialogue	Global and comprehensive targeting to keep temperature increase below 2ºC	All countries, particularly non-Annex I	Historical responsibility, capability and potential to mitigate	(1) Annex II countries; (2) other Annex I countries; (3) NICs (4) other developing countries, and LDCs	Ott et al. 2004
Greenhouse Development Rights	Involving everyone who is above the development line	All countries, particularly developed countries	Equality (Egalitarian) Limited Responsibility, Historical Responsibility, Capacity (Basic Needs)	Poor and rich	Baer et al. 2008
Graduation and Deepening	Involving emission targets for developing countries whose combined GHG/cap and GDP/cap are high	Non-Annex I	Polluter pays, ability to pay, comparability	Developing countries with (1) GI > Annex-B ave (2) Annex-B ave > GI > the lowest OECD (Annex II) (3) the lowest OECD country> GI > the lowest Annex-B (4) GI < the lowest Annex-B country	Michaelowa et al. 2003 and Michaelowa et al. 2005
Sao Paulo Proposal	To encourage developing countries to keep emissions low	All countries, particularly non-Annex I countries	Responsibility, capability, comparability	Non-Annex - I graduation threshold increases as the population rises, decreases as the GDP/cap and GHG/cap increase	Basic, 2007

Table 2-5 Continued

Approaches	**Aim**	**Scope**	**Equity-related Argument/Principle**	**Differentiation Groups**	**Proposed by**
Contraction and Convergence	Linearly convergence per capita emissions in a constant carbon budget	All countries	Precaution, Egalitarianism		Global Common Institute (1995)
The Concentric Differentiation	All parties participation in the emission reduction	All countries	Responsibility and capability	Five groups	The Government of Brazil (2014)

2.3 Literature on Composite Indices for Combatting Climate Change

In the literature, there are some studies focusing on indices for measuring countries' effort in combatting climate change. These indices present all efforts with their indicators in a single overall index. In this section, three indices on combatting climate change are reviewed. These are Climate Change Performance Index, the Cooperation Index on Climate Change (CI) and the Climate Change Cooperation Index (C3-I).

Climate Change Performance Index (CCPI) that has been developed in 2005 by Germanwatch, ranks countries' performances according to different indicators of climate actions (Burck, Hermwille, & Bals, 2013). CCPI has four components – emissions, efficiency, renewable energies and climate policy. CCPI uses fifteen indicators to create a single composite index (Burck, Hermwille, & Bals, 2013). "Climate policy", "efficiency" and "renewable energies" are responsible for 40 % and "level of current emissions" and "development of emissions" are responsible for 60% of each country's composite index (Burck et al., 2013). The CCPI's score is obtained from the weighted average of the achieved scores in the separate indicators (Burck et al., 2013). The main challenge for CCPI index is that there is a vast diversity of countries with different geographical conditions, historical emissions and economic capabilities (Burck et al., 2013). However, this index has not considered the possible correlation among the indicators which may overestimate the index value. Additionally, social dimension of capabilities in order to mitigate emissions is not taken into account when creating this index.

The second index is the **Cooperation Index (CI)** created in 2008 by Baettig and his friends (2008). They argue that cooperative countries commit to solve global common problems within the framework of the UNFCCC. They focus on five indicators to estimate countries behavior within the climate change regime. The first two indicators quantify being a party or ratification of the UNFCCC and the Kyoto Protocol. Three other indicators quantify reporting, payment of financial contributions, and mitigation of CO_2 emissions. The aggregation of all five indicators results in the CI. The first indicator (UNFCCC Indicator I_U), which consists of two sub-indicator, considers the position of countries, whether ratifies or not the UNFCCC and promptness to ratification. Second indicator (Kyoto Protocol I_{KP}), similar to the first indicator, consists of a willingness and promptness part of the KP. The third indicator (Reporting

Indicator I_R), which measures submissions of national communication and fastness of this submission, has two equally weighted sub-indicators. Forth indicator (Finance Indicator I_F) evaluates the countries' annual financial contributions to the core budget of the UNFCCC. Fifth indicator (Emission Indicator I_E) assesses the level and trend of each country's per capita CO_2 emissions and depends on the per capita gross domestic product (GDP). To aggregate these indicators to obtain the CI, each individual indicator is equally weighted, but the Emission Indicator is double weighted. The reason for doubling is that the most important factor in climate policy is considered to be stabilization of GHG emissions. Thus, the CI indicates that the climate change is a multi-dimensional problem and combatting climate change needs capable countries. However, when creating CI, social and technical dimensions are ignored. And also, if the equally weighted indicators are not independent of each other, then the CI could overestimate countries' efforts.

The third and last index study is **Climate Change Cooperation Index** (C3-I) developed by Bernauer & Böhmelt (2013). It is based on the indicators of the Cooperation Index created by Baetting and his friends (2008). Bernauer & Böhmelt (2013) changes aggregation policy of the Cooperation Index during creation of C3-I though equal weights for policy and emissions components. While The Climate Change Performance Index (CCPI) has less weight on the climate policy components, the Cooperation Index (CI) has greater weight on the policy components. C3-I supports importance of both emissions and policy components and aggregates both components equally. The C3-I index similarly lacks of consideration of social and technical indicators and their correlation.

CHAPTER 3

METHODOLOGY

In this study, to quantify principles of CBDR and RC and to differentiate countries' emission mitigation responsibilities, different types of economic, social, technological, environmental variables are used. To compare the countries national circumstances in terms of two principles, CBDR Index and RC Index are created. Moreover, countries are grouped with regard to CBDR and RC indices. The scope of the analysis is limited to 50 countries because of availability of data for these countries. The novelty of this analysis is based on selected variables with different aspects and techniques applied for creating composite indices. In terms of originality, in addition to economic variables, social and technical variables are also considered when determining RC. In the context of CBDR, in addition to current and historical emissions, intensity indicators, sector specific and consumption based indicators are also taken into account while introducing indices.

3.1 Steps for creating composite indices

Composite indices (CIs) which are increasingly recognized as a useful tool in policy analysis, 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 this study, two different methods are used while creating indices. In the Figure 3-1, the different steps of two methods are shown. Same variables are used for both methods. In method 1, indicators are normalized through min-max technique, and in method 2 standardization (z scores) are used for normalization.

In method 1, before creating CBDR or RC indices, dimension indices are created. In order to determine the weight of each indicator for a dimension index, the statistical technique called "principal component analysis" (PCA) is applied (step-3). Then, each indicator is aggregated within the calculated weights by PCA in the dimension index (step-4). After that, for calculating the overall or final index (CBDR and RC indices), dimension indices are weighted by PCA and then aggregated (step-5). After obtaining the index scores, countries are grouped by cluster analysis (CLA) (step-6). The advantage of introducing dimension index is to observe the countries national circumstances in terms of economic, social, technological, emission intensity and emission level aspects. Particularly on the capability issue, knowing countries more capable areas can provide precise information about countries' specific ability. This analysis can also assist the policy makers while allocating emission reduction and providing different types of assistance to vulnerable countries in the context of emission mitigation.

In method-2, instead of dimension indices for both indices, all related indicators for CBDR and RC are used in PCA (step-3). Then, these components are aggregated according to the results of each components eigenvalue (step-4). In the next step, CBDR and RC indices are calculated for each country (step-5). Finally, countries are grouped according to the CBDR and RC index scores. One of advantage of method-2 is to provide flexibility for introducing possible new indicators into the PCA. In this study, the scope of indicators is limited because of the non-availability of data. When new data can be collected and reported, the range of indicators of PCA can be easily expanded. The other advantage is to be able to conduct a similar analysis for a small group of country with more data.

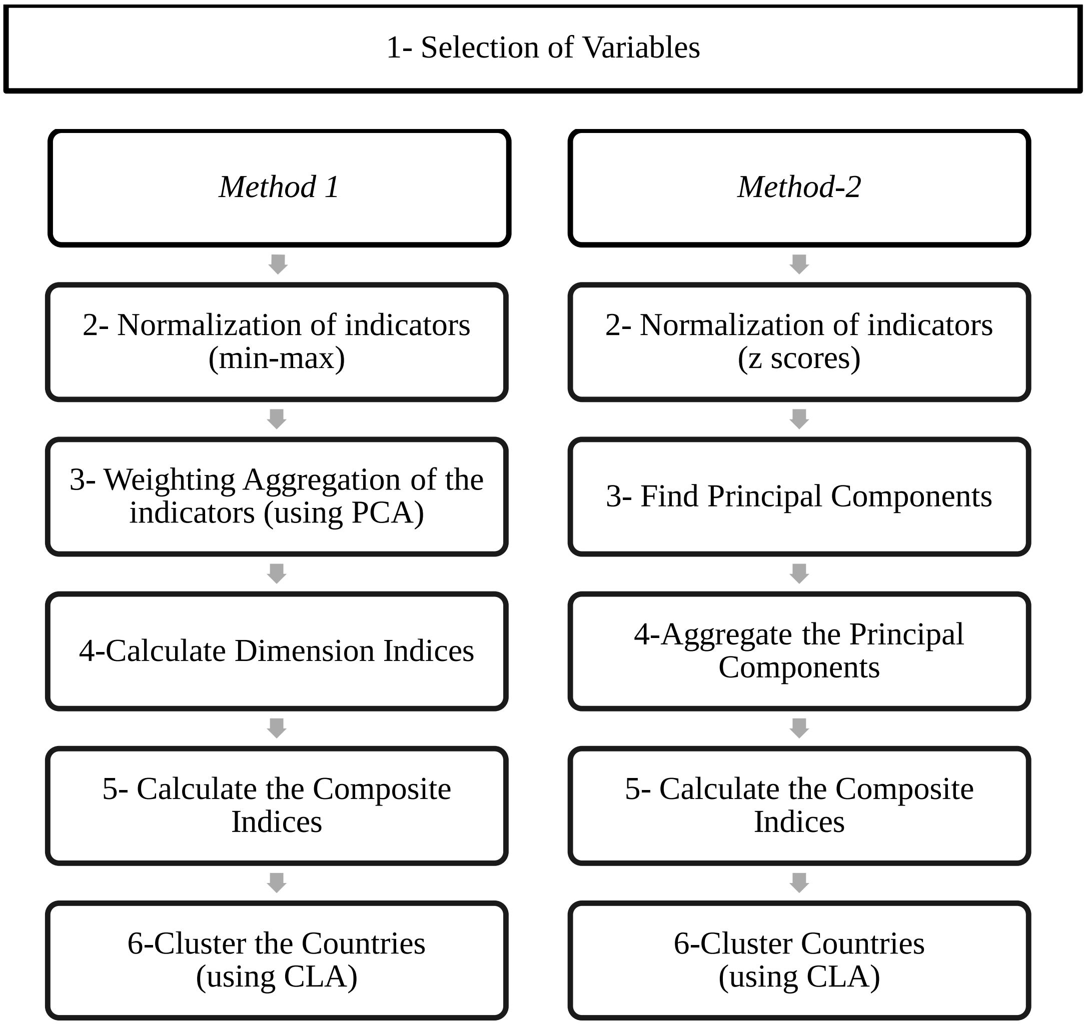

Figure 3-1: Steps for creating composite index

3.2 Selection of Variables

Selection of variables is the first step of creating composite index. In the climate change literature, different types of indicators have been selected to explain countries' emissions profile, responsibilities, abilities and performance for combatting climate change. As explained in chapter 2 there are different climate change performance indices including total GHG emissions, per capita emissions, policies for reducing emissions, financial contribution, etc. 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. One of the novelty of this study is to concern social and technical variables into the index.

It is no doubt that the selected variables should be on the basis of their analytical soundness, measurability, country coverage and relevance to the phenomenon (Nardo et al., 2008). This section consists of two parts: variables for CBDR and variables for RC. The scale, scope and source of indicators are summarized in Table 3-1. Also the values of all selected variables for 50 countries are listed in Appendix.

Table 3-1: Selected Variables

Type	Aspect	Definition	Scale	Time	Source
GHG emissions	Responsibility	Total emitted GHG emissions in a year	ton CO_2e	2010	(WRI, 2014)
Per capita GHG emissions	Responsibility	GHG emissions divided into population of a country	Per capita ton CO_2e	2010	(WRI, 2014)
Consumption based per capita CO_2 emissions	Responsibility	per capita emissions originated and embodied from consumed domestic and imported goods and services	Per capita ton CO_2e	1990-2010	(OECD, 2014)
Sectoral per capita emissions	Responsibility	Per capita emissions from energy, industry, agriculture and waste sectors	Per capita ton CO_2e	2010	(WRI, 2014)
Cumulative emissions since 1850 and 1990	Responsibility	(1) Cumulative CO_2 emissions from fossil fuel combustion and cement production since 1850 (2) Cumulative all GHG emissions since 1990	ton CO_2e	Since 1850 and 1990	(CDIAC, 2014; WRI, 2014)
Change of per capita emissions	Responsibility	Change of emission intensity of population according to percentage change of per capita emissions between 1990 and 2010	percentage	1990-2010	(WRI, 2014)
Change of GHG emissions per GDP	Responsibility	Change in the emission intensity of economy based on percentage change of GHG emissions per unit GDP	percentage	1990-2010	(WRI, 2014)
GHG emissions per GDP	Responsibility	GHG emissions divided into GDP of a country	ton emissions per 1 US $ 2010		(WRI, 2014)
GDP	Economic Capability	GDP (PPP) is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products	Constant, 2005$ billion US	2010	(WDI, 2013)

Table 3-1 Continued

Type	Aspect	Definition	Scale	Time	Source
Gross Savings	Economic Capability	The percentage of gross national income less total consumption, plus net transfers in GDP of a country	Percentage of GDP	2010	(WDI, 2013)
Per Capita GDP	Economic Capability	GDP divided into population of a country	Per capita constant, 2005$ billion US	2010	(WDI, 2013)
Literacy rate	Social Capability	The percentage of the population age 15 and above who can read, understand and write on their everyday life	percentage	2010	(CIA, 2014)
Unemployment rate	Social Capability	The percentage economically active population who are without work but available for seeking work	Percentage	2010	(WDI, 2013)
Income inequality	Social Capability	Deviation of the distribution of income within a country from a perfectly equal distribution	Gini Coefficient	2010	(UNDP, 2013b; WDI, 2013)
Poverty rate	Social Capability	The percentage of the population living below the national poverty line	percentage	2010	(UNDP, 2013b)
Secondary school enrollment	Social Capability	The percentage of the population of official overall secondary education age in a country	percentage	2010	(UNDP, 2013b; WDI, 2013)
Number of hospital beds	Social Capability	The number of hospital beds include inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers	Per 10,000 people	2010	(WHO, 2013)
Patent numbers	Technical Capability	Patents granted to residents and non-residents within a country	Per million people	2010	(UNDP, 2013b)

Table 3-1 Continued

Type	Aspect	Definition	Scale	Time	Source
High technological export	Technical Capability	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery	Percentage of manufactured exports	2010	(WDI, 2013)
Research and development Expenditure	Technical Capability	The percentage of expenditure (public and private) for increasing knowledge and innovation	Percentage of GDP	2010	(UNDP, 2013b)
Renewable energy	Technical Capability	The percentage of utilization of renewable energy sources in the total energy supply	Percentage of total primary energy supplies	2010	(IEA, 2013b)

3.2.1 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 CO_2 since 1850, cumulative GHG since 1990, consumption based per capita CO_2 emissions, and sectoral per capita GHG emissions are used as indicators.

According to the polluter pays principle, the amount of current emissions as a parameter of the pollution can determine countries' share of responsibility. It is very likely that their GHG emissions cause the climate change problem (IPCC, 2007) so major emitter countries should be more responsible than others. Therefore, it is expected that major emitters with this burden should mitigate more emissions through changing their policies (Karousakis et al., 2008). In order to introduce CBDR index value for a country, **current GHG emissions** can be considered as one of the main indicators. Preliminarily, this indicator also provides information about the differentiation of responsibilities with regard to countries' emitted emissions level.

In the current annexes of the UNFCCC, giving the leading role to the Annex-I countries for emission mitigation does not reflect the factual polluter pays principles anymore. Because non-Annex I countries emission level has increased enormously between 1990 and 2010. The global share of current GHG emissions (as of 2010) of Annex-I and non-Annex I are different than those in 1990 which is the most attributed base year in the UNFCCC. In 1990, the source of emissions from non-Annex I countries consisted of 41% of global emissions; but in 2010, this share has reached to 59% (Figure 3-2). The change in the share of GHG emissions brings the concern for the obligation of non-Annex I countries emission reduction. The increasing emissions from non-Annex I countries also show that without any responsibility of these countries, the ultimate objective of the UNFCCC might not be reached. Therefore, in this study, GHG emissions in 2010 for all 50 countries is used without divergence among Annexes of the UNFCCC.

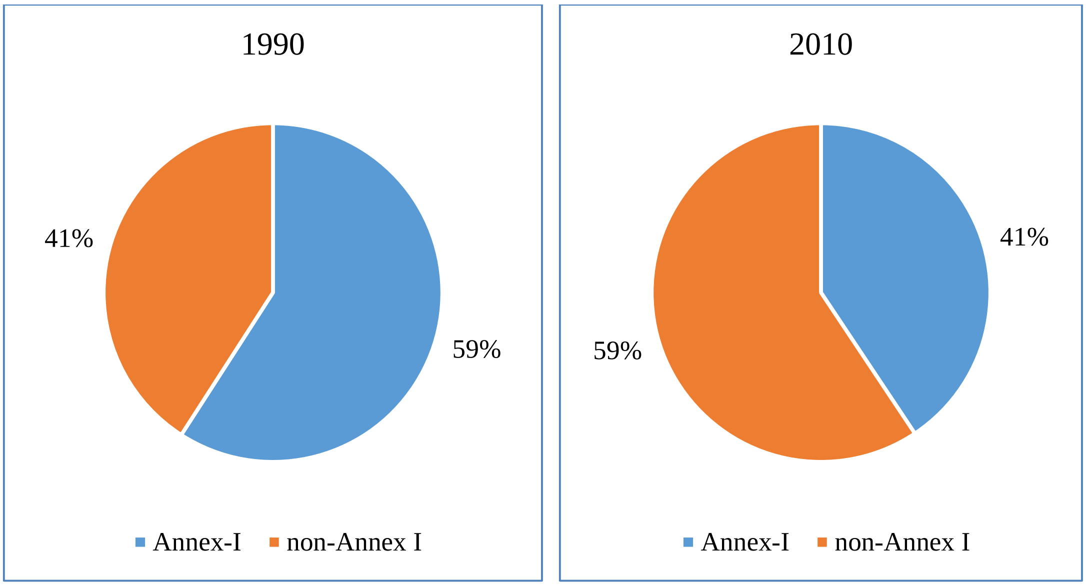

Figure 3-2: The GHG Emissions of Annex-I and non-Annex I in 1990 and 2010

As mentioned in the chapter two, according to egalitarianism, all people in the world have a right to share a global common atmosphere. Any person who is emitting more GHG emissions to the atmosphere, should be expected to make more commitments for solving the common problem. This policy is based on the equality principles of equity. When this policy converted from person's rights to country's rights, it can be taken the average of a country's per capita emissions. When any country which has a higher **per capita emissions** than others, its responsibility share should be higher. For these reasons, the level of per capita emissions is considered as an essential indicator to calculate CBDR index.

Besides, domestic or production based GHG emissions in a country, some studies emphasize relation 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). Because emissions embodied in trade and consumption are rapidly increasing, and there is a growing gap between production emissions and the emissions associated with consumption (J. Barrett et al., 2013). The coverage of consumption-based GHG emissions is inclusion of GHG emission associated with products and services to the country where they are consumed, and exclusion of GHG emissions related to exported products (Csutora & Vetőné mózner, 2014). The effects of consumed products and goods on the generated emissions[6] through carbon leakage from developed to developing can be considered via consumption based accounting. Because, carbon leakage and trade issues are common among countries' economies, consumption based emissions cannot be neglected. Therefore, the needs for adoption of **consumption-based** GHG emissions accounting has started to be discussed in the climate policy domain (Kokoni & Skea, 2013). In addition to factual figures in the consumption based accounting, this indicator is also related to consumer pays principle. Therefore, in this study, consumption based per capita emission is taken into account for the determination of responsibilities.

In addition to aggregated per capita emissions for both consumption and production based accounting, **sectoral per capita emissions** are also used in this study. 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 being discussed. For this reason, it can be necessary to know country's each sectoral emissions. In terms of sharing responsibility, sectoral emissions can impact burden either positively or negatively. When a country has certain achievements in a specific sector in reducing the emission intensity for a given period, this achievement can help to reduce the country's responsibility. On the other hand, if any country's per capita emission in a specific sector increases continuously, this might lead to increase the country's share of responsibility according to sectoral approaches. For these reasons, energy, industry, agriculture and waste per capita emissions are considered in the calculation of CBDR index.

As reported by the IPCC, the global climate change problem is a consequence of the accumulated CO_2 emission in the atmosphere (IPCC, 2007). The anthropogenic GHG emissions has increased since the industrial revolution. In other words, current and expected changes in global climate system is a result of stocked cumulative emissions

[6] Consumption based emissions = production based emissions + imports emissions – exports emissions

(Kolstad et al., 2014). In this study, cumulative emissions are classified as historical responsibility and historical contribution according to base year as 1990 and 1850, respectively. The reason behind selecting different years as historical emissions is based on ongoing discussions about the start year in climate policy literature (Ashton & Wang, 2003; Kolstad et al., 2014; Mattoo & Subramanian, 2012; Rive et al., 2006). Just before 1990 the IPCC's first report was announced and all countries were aware about the climate change problem. Thus starting by 1990 means to consider the historical responsibilities. Historical contribution focusing on the past emissions of countries has caused the increase in global average temperature (Müller et al., 2009). However, in this study, it is assumed that the past emissions cannot be eliminated during the determination of responsibilities. Therefore, start years as 1850 is also selected in the context of historical contribution. This motivation is also related to the polluter-pays principle. Thus, both historical contribution and historical responsibilities are considered in the CBDR.

Although, annual GHG emissions of non-Annex I countries has started to exceed to Annex-I's in 2003 (Figure 3-3), in terms of historical contributions (since 1850), Annex-I's emissions are higher than those of non-Annex I. Between 1850 and 1990, non-Annex I countries were responsible for 17% cumulative emitted GHG emissions. After two decades, the contribution of non-Annex I countries have reached to 28%. This fact shows that non-Annex I countries have historically less responsibilities than Annex-I. On the other hand, emissions from non-Annex I countries have been increasing more than Annex-I's, meaning their share of historical responsibilities related to past emissions are growing every year. When GHG emissions effect on climate change has been scientifically proofed in 1990 by IPCC first report, it is accepted that countries should be more responsible to limit their GHG emissions. However, since the UNFCCC does not give any responsibility to non-Annex I countries for their emissions, the share of historical emissions of non-Annex I countries has raised enormously.

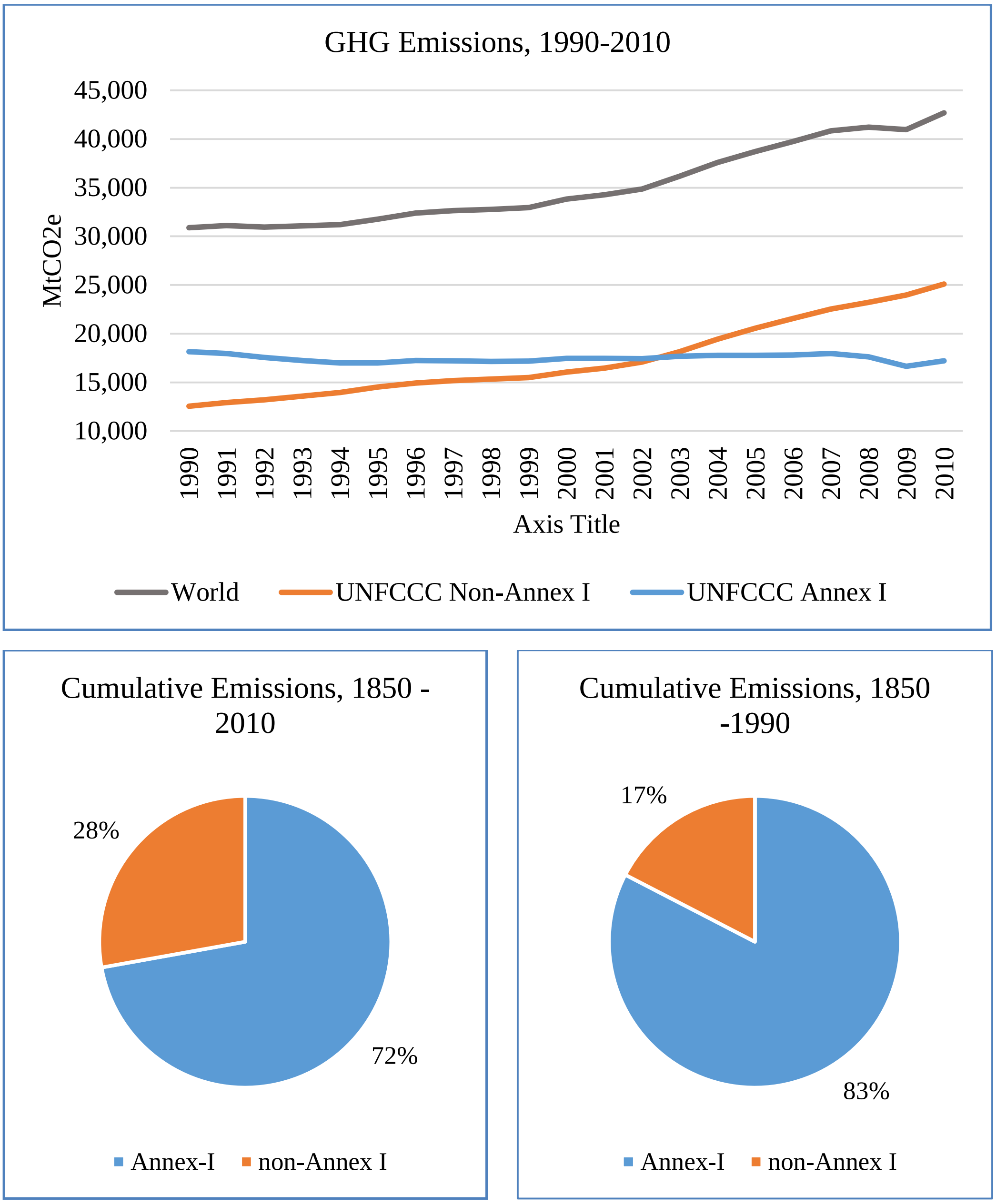

Figure 3-3: Trends and Cumulative Emissions of Annex-I and non-Annex I

The trends and change of per capita emissions have an impact on the share of responsibility. This change may be either positive or negative on country's responsibility. The percentage change between 1990 and 2010 are derived in order to calculate change of per capita emission. According to trends between 1990 and 2010, it can be observed that Annex-I's per capita emissions have been declining, but those of non-Annex I have been rising (Figure 3-4). Overall, the average per capita emissions is almost steady for this time period in the world. Annex-I countries' efforts for reducing per capita emissions and non-Annex I countries' lack of concerns to limit their emissions should have a response when their CBDR index are being calculated. It is assumed that while the efforts for limiting emissions has reduced the burden of responsibility, insufficient efforts and no actions for mitigation of emissions have increased the responsibility burden.

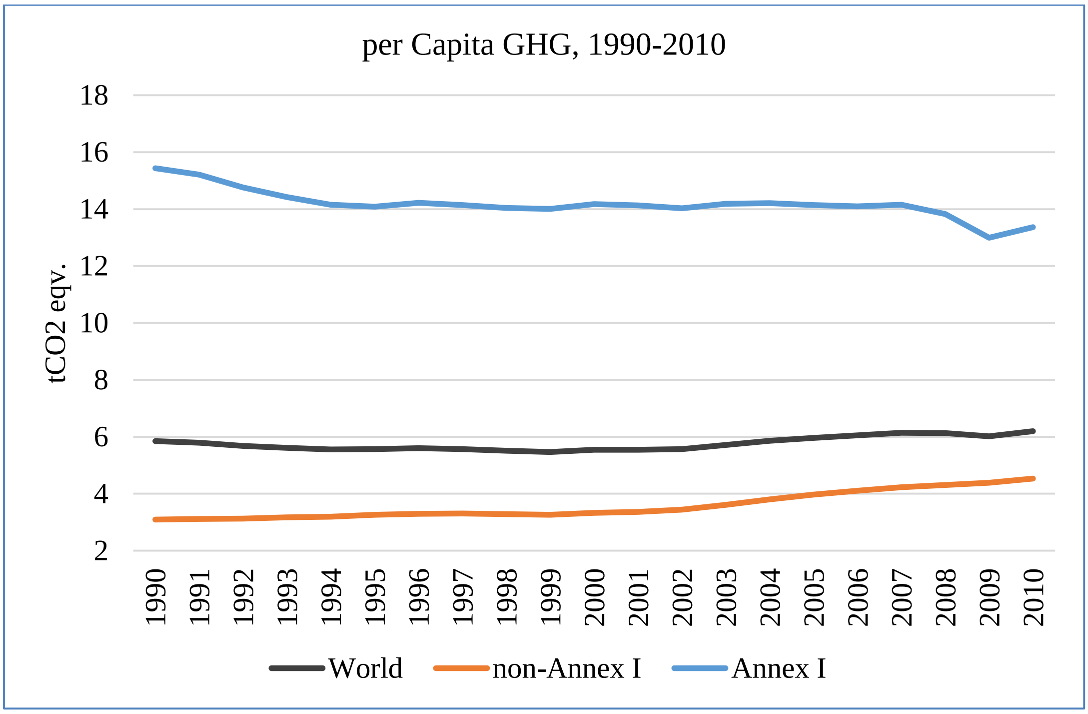

Figure 3-4: Trends of per Capita GHG Emissions between 1990 and 2010

Change of GHG emission intensity of economy for a certain period of time can explain the efforts of countries to reduce emission intensity of a country. 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.

3.2.2 Variables for RC Index

The capabilities are essential to allocate responsibilities fairly under the UNFCCC. In the literature, there are some indicators such as GDP and per capita GDP used to determine capabilities. However, these indicators are criticized because of their insufficiency to represent countries' actual capabilities and it is suggested that different dimensions should be considered through RC to determine countries national circumstances as stated in chapter 2 (Müller & Mahadeva, 2013b).

In this study, it is assumed that in addition to economic capability, RC has different dimensions such as technological and social capability with appropriate indicators. 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 percentage of research and development (R&D) expenditure in GDP, patents number in one million people, the percentage 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.

Many studies use the **GDP** as an indispensable indicator for determination of capabilities (Michel G.J. den Elzen, Höhne, & van Vliet, 2009; Karousakis et al., 2008; Müller & Mahadeva, 2013b). GDP generally determines countries' economic magnitude. Similar to GHG emissions, countries' GDP have significantly changed since the early 90s. When the UNFCCC was being prepared in 1992, non-Annex I countries' GDP share in the globe was 32%. Within two decades, the GDP share of non-Annex I countries have reached to almost half of the global GDP. It is difficult to conclude that all non-Annex I countries are economically incapable of reducing their emissions. Therefore, accepting all non-Annex I countries for receiving financial resources cannot be in line with the principle of RC.

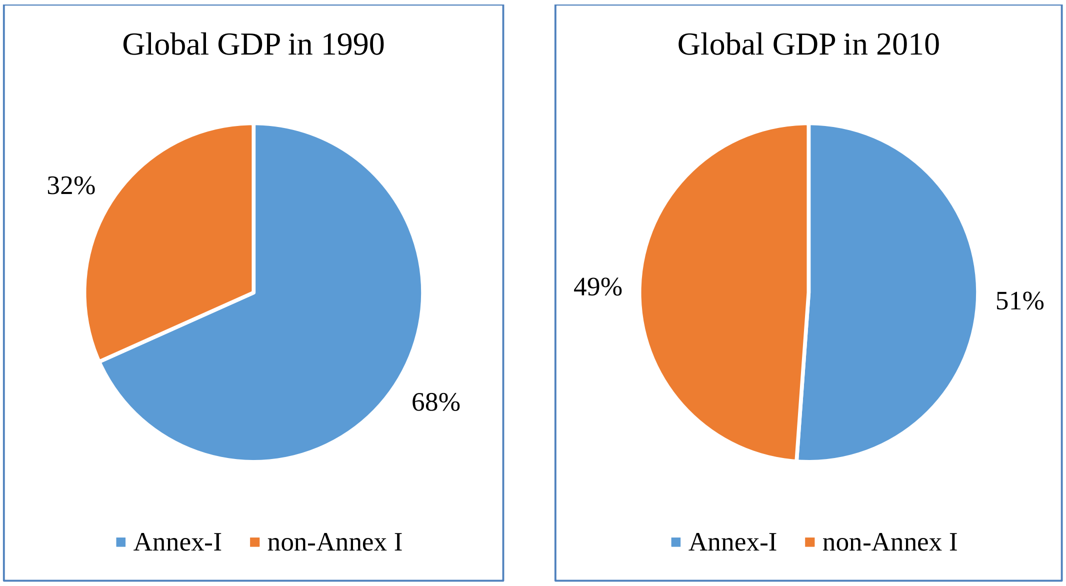

Figure 3-5: Global GDP Share of Annex-I and non-Annex I in 1990 and 2010

Besides GDP, **per capita GDP** provides information about the society's overall average income, and can roughly reflect the general prosperity of a country. It is also frequently used to assess the economic capability to mitigate GHGs (Karousakis et al., 2008), because emission reduction needs some investment and finance. Therefore the level of the societies' ability to pay gain importance. Thus, per capita GDP can still be accepted as a significant indicator for determining economic capability.

Mitigation of emissions needs strong and resilient economies. The impacts of climate change might severely affect countries' economic recovery. Moreover, the least amount of debt can also increase countries' economic capabilities and resilience. When combating climate change, countries' public and private investments particularly on high technology, climate friendly and low carbon projects are very important which depend on the country's economic conditions. To be able to finance these types of investments and projects, **gross savings** is used in the economic capability dimension of this study.

In terms of technical capabilities, technological and scientific **research and development (R&D)** are necessary for innovative solutions for combatting climate change. According the IPCC's report economically it is almost impossible to stabilize

GHG emissions in the atmosphere without R&D (Ottmar Edenhofer et al., 2014). This indicator can provide information about the countries' technological and scientific capacities to develop, deployment and diffusion of climate friendly technologies. R&D expenditure in both public and private is also essential to increase knowledge and innovation of capacities of societies (UNDP, 2013a). To determine any countries technological capabilities, R&D expenditure shares in GDP is highly related to ability to mitigate climate change. 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.

High technology industries such as aircraft, computers and pharmaceuticals provide information about the structure and preferences of manufacturing industries in a country (WDI, 2013). 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 (Ottmar Edenhofer et al., 2014). **Renewable energy** sources, including hydro, solar, wind, geothermal, municipal waste, etc. (IEA, 2013b), in total primary energy supply can be considered with the progress in R&D and availability of these sources. In fact, many studies consider the renewable energy sources as one of the main solutions to mitigate GHG emissions (IEA, 2013a, 2013b; IPCC, 2011). Physical availability and technological utilization of renewable energy sources can provide significant capability for reducing GHG emissions.

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 taken to show a county’s capacity deficiency in terms of general knowledge on emission reduction policies. Educated societies are essential to combat climate change, and educational indicators can be used to have an idea on social capability of a country. Education is also an essential tool for raising awareness as well as realizing 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 national circumstances of countries and it is considered as a 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 the country can create a capacity to mitigate emission for combatting climate change (UN, 2014).

People with decent jobs and well employed can be more active and careful for thinking climate change problem in their daily lives. 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 economic situation as well. Unemployment can be a problem in societies because unemployment leads to social exclusion and losses of self-confidence of unemployed groups (Sen, 1999). This might reduce countries’ social resiliencies and capabilities during impacts of climate change. Therefore, this indicator is selected to be used in social capability issue.

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). 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). Although many of the European countries are high income developed countries, they were not ready to sufficiently recover the unexpected disaster. Many people died in high heat wave and the media stressed the insufficient hospital bed capacities of these countries (Stott et al., 2004). In this study, the number of hospital beds including inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers are used as a social indicator (WDI, 2013).

Income inequality can be considered as a measure of the development level of any country (Baer et al., 2008). It can also provide information about the emission distribution within a country between different income levels (Fleurbaey et al., 2014). This indicator is essential for determining the economic and social capabilities of countries' citizens for mitigation of climate change. Countries with high income inequality can have more challenges to reduce their emissions.

Additionally, poverty which is a kind of shortage of income, causes of 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. Poverty creates challenges such as following fossil-fuel and emission intense conventional development pathway (Fleurbaey et al., 2014). In addition to this, poverty eradication through economic and social development can be the first priority in the developing countries' agenda (Fleurbaey et al., 2014). Similar to income inequality, poverty gap is a measurement of development level of a country (Baer et al., 2008). In the context of reducing vulnerability that is related to climate change should be ensured to build resilient societies (UN, 2014). For this reason, this indicator is used as it is relevant to show capabilities and resilience of countries when any country faces to environmental, social and economic challenges.

3.3 Normalization

Indicators can have different measuring units and scales, so they should be normalized in a common scale before starting the weighting and aggregation steps (Nardo et al., 2008). There are different types of normalization methods such as min-max, standardization (z-scores), ranking and categorical scales.

Min-Max is applied by subtracting the minimum value from the exact value and dividing by the range of the indicator value. Each indicator X_k is transformed into normalized indicator I_k as follows:

$$I_k = \frac{X_k - minX_k}{\max X_k - \min X_k} \tag{1a}$$

Where *min* (X_k) and *max* (X_k) are the minimum and the maximum value of X_k across all countries, respectively. In this way, the normalized indicators I_k have values lying between 0 and 1. The used statistical package program (SPSS) can normalize all indicators in the analysis.

Standardization (z-scores) technique is also used in this study. In order to obtain each normalized indicator, I_k, of X_k; the average of X_k, μ; and standard deviation σ are calculated as below equation.

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

In method 1, min-max normalization technique is used, because min-max method prevents the negative values in the calculation through being in the interval between 0 and 1. Additionally, min-max normalization increases the effect on the composite indicator more than the other normalization method within a small interval (Reisi, Aye, Rajabifard, & Ngo, 2014).

In method-2, standardization technique is used, because there is no need to concern negative values of normalized indicators anymore. Also the weights of normalized indicators and dimension indices are not calculated. All scores components are directly calculated in the method 2.

3.4 Method 1

3.4.1 Weighting

While creating indices, the weighting methods of the indicators is highly crucial. There are mainly three weighting methods: equal weighting, weighting based on expert judgments or opinions and statistical methods (Jollands, Lermit, & Patterson, 2003; Reisi et al., 2014).

The *equal weighting* method has certain risks. One of them is related to double counting problem. Similar indicators in a composite index can measure the same dimension or thing so this leads to unbiased measurement (Freudenberg, 2003; Reisi et al., 2014). The other risk of equal weighting is to accept equal importance of all indicators within the composite index (Reisi et al., 2014). Due to attainment of the equal importance for the indicators are usually impossible and might change from case to case, so equal weighting can weaken the analysis. Secondly, *weighting based on expert judgments and opinions* can be highly subjective, so the weight of different indicators may lead to biased decision making (Nardo et al., 2008). The third and the most appropriate method for weighting is *statistical models* (Jollands et al., 2003; Reisi et al., 2014). There are mainly three statistical methods for weighting the indicators: Data Envelopment Analysis, Benefit of Doubt and Principal Component Analysis (PCA) (Reisi et al., 2014). According to Kao and Hung (2005) the PCA method is better than Data Envelopment Analysis and Benefit of Doubt. PCA which relies on the variation and co-variation of the data matrix to construct weights in the index, can be used for comparing different indicators on several aspects (Reisi et al., 2014). PCA is also independent from opinions or expert judgments and subjective weighting (Freudenberg, 2003; Reisi et al., 2014).

3.4.1.1 Principal Component Analysis

The aim of the PCA is to reduce the large number of variables into a smaller number of components which represents most of the variance in the variables (Verma, 2013). PCA attempts to maximize the 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:

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

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 combination 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).

As mentioned earlier, PCA is used for creating CBDR and RC indices. In method 1, PCA is applied in order to find weights of indicators in the related dimensions. In method 2, PCA is employed to obtain each principal components.

3.4.1.2 Determination of weighting factors and aggregation

Dimension indices (DI) such as social, economic, and technical for RC index and the level and intensity for CBDR index are calculated. For each dimension index, to calculate each dimension index, intermediate dimension indicators (IDI) are calculated based on normalized indicators, weights of each component obtained by PCA (Gomez-Limon & Riesgo, 2008; Reisi et al., 2014) as shown below equations:

$$Intermediate\ Dimension\ Indicators\ (IDI)_j = \sum_{k=1}^{n} W_{kj} I_k \quad (3)$$

Where IDI, intermediate dimension indicators; j, each principal component; W_{kj} represents the weight of the indicator k in the component j; I, normalized indicator; k, number of indicator. The W_{kj} is calculated from the factor loading and eigenvalues by using PCA:

$$W_{kj} = \frac{(factor\ loading_{kj})^2}{eigenvalue_j} \tag{4}$$

For each dimension index, intermediate dimension indicators are multiplied with eigenvalue obtained by PCA as shown below equation:

$$Dimension\ Index\ (DI)_j = \sum_{j=1}^{k} \alpha_j\ IDI_j \tag{5}$$

Where DI, dimension index; j, each principal component; IDI, intermediate dimension indicator; k, number of intermediate dimension indicators. The α_j is also the weight applied to intermediate dimension indicators. The equation below gives the weights of each intermediate dimension indicators.

$$\alpha_j = \frac{eigenvalue_j}{\sum_{j=1}^{m} eigenvalue_j} \tag{6}$$

In order to obtain composite indices for both CBDR and RC, dimension indices are weighted and then aggregated as follows:

$$I_{CBDR} = \sum_{j=1}^{m} \beta_j DI_j \tag{7a}$$

$$I_{RC} = \sum_{j=1}^{m} \beta_j DI_j \tag{7b}$$

β is also the weight applied to dimension indices. In equation below gives the weights of each dimension index is given.

$$\beta_j = \frac{eigenvalue_j}{\sum_{j=1}^{m} eigenvalue_j} \tag{8}$$

3.4.2 Dimensions of CBDR and RC Indices

As explained in previous chapter, there are two dimensions of CBDR Index (Figure 3-6). The first dimension is called emission level, including GHG emissions and historical emissions since 1850 and 1990. The second dimension is related to the emission intensity of countries. This dimension includes per capita GHG emission, change of per capita GHG emission (between 1990 and 2010), GHG emissions per unit GDP, change of GHG emission per unit GDP (between 1990 and 2010), consumption based per capita emissions and per capita sectoral emissions. Many countries' emissions are correlated to their economic activities. Before creating indices, it is observed in this study that the higher GDP the higher GHG emission level will be. It is also observed from raw data that the rate of economic growth is not the same as the rate of GHG emissions for a certain period of time. Some countries follow more climate friendly economic growth pathway than others. In order to take into account of these countries' efforts for emission reduction, emission intensity dimension is tracked in terms of their decreasing contribution to the problem. The motivation for intensity dimension index is to include countries' efforts towards a lower carbon economy or less emission intense GDP growth. For RC, there are three dimensions. The first dimension is related to the economic indicators such as GDP, per capita GDP, and the percentage of gross savings in GDP. These three indicators can measure the economic capability level of a country. Second dimension is based on social indicators, namely poverty rate, income inequality (Gini Coefficient), secondary school enrollment, unemployment rate and literacy rate. These indicators can assist to explain countries' social development level. The third and last dimension is related to the technological indicators. These indicators are research and development, the number of patents gained in a country, the usage of renewable energy resources and the percentage of high technological products in the exportation.

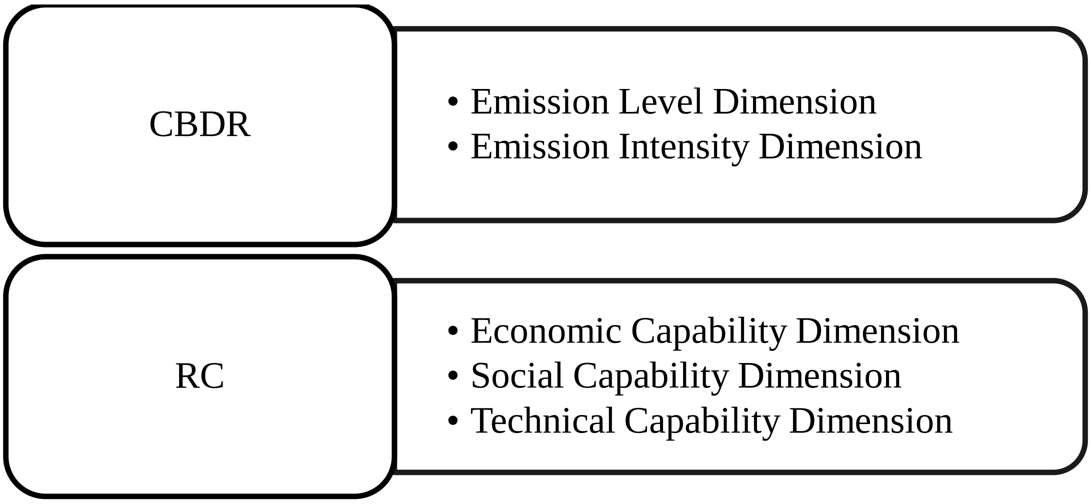

Figure 3-6: Dimensions of CBDR and RC

3.4.3 Cluster Analysis

In this study, Cluster analysis (CLA) is applied for grouping the 50 countries based on CBDR and RC index. CLA is conducted for both method 1 and method 2. The aim of CLA is to group cases of data based on the similarity, so a group or cluster consists of homogenous and similar variables or subjects (Anderberg, 1973; Verma, 2013). 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. The equation of the Euclidean distance is given below:

$$de_{ij} = \sqrt{\sum_{k=1}^{n} \left(X_{ik} - X_{jk}\right)^2} \tag{9}$$

where X_{ik} is the measurement of i^{th} cases on k^{th} variable, X_{jk} is the measurement of j^{th} cases on k^{th} variable, and n is number of variables.

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 by using CLA can provide appropriate segregation among groups without losing any information in indices scores.

3.5 Method 2

Different from application area of PCA in the method 1, PCA in method 2 finds the number of components through eigenvalues of each principal component and exclude highly correlated indicators. In the method-2, all CBDR indicators such as GHG, cumulative GHG since 1850 or 1990, per capita GHG, GHG emission per unit GDP, etc. are not separated into either emission level or emission intensity dimension index. All these indicators are used by PCA for finding the number of principal components to present the CBDR. Similar steps are also conducted for RC index. The results of the PCA are expected to give number of principal components and weights of each principal component as follows:

$$I_{CBDR} = \sum_{j=1}^{m} \gamma_j PC_j \quad (10a)$$

$$I_{RC} = \sum_{j=1}^{m} \gamma_j PC_j \quad (10b)$$

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

$$\gamma_j = \frac{eigenvalue_j}{\sum_{j=1}^{m} eigenvalue_j} \tag{11}$$

CHAPTER 4

RESULTS

In this chapter, the results of CBDR and RC indices are presented for method 1 and method 2.

4.1 Results of Method 1

Method 1 creates both indices based on dimensions. Each dimension and overall index scores are presented in the following sections.

4.1.1 Creating the CBDR Index

CBDR index consists of two dimensions: emission level and emission intensity.

4.1.1.1 CBDR - Emission Level Dimension Index

In order to create emission level dimension index, three indicators are selected. They are GHG emissions, cumulative CO_2 emissions since the industrial revolution (1850), and cumulative GHG emissions since 1990. These indicators are useful for measuring the current and historical emissions. In order to create this dimension, PCA is employed. Before construction of dimension index and determination of the weight of each indicator, correlation analysis and KMO test for PCA are conducted. Table 4-1 presents the correlation matrix results of three indicators. According to this, cumulative GHG emission since 1990 is highly correlated with current GHG emissions and cumulative CO_2 emissions since 1850. In addition to the correlation problem, KMO test result is smaller than 0.500 (KMO is 0.468, Table A- 8 in Appendix). Therefore, to ensure appropriate indicators for PCA, another indicator set is selected.

Table 4-1: Correlation Matrix of Emission Level Indicators

	Cum. GHG	Cum.GHG.1990	Cum.CO_2.1850
Cum. GHG	1.000		
Cum.GHG.1990	0.963	1.000	
Cum.CO_2.1850	0.783	0.916	1.000

In order to obtain desired KMO test results, cumulative GHG emissions since 1990, which is highly correlated with other indicators, is excluded from the analysis. After doing that, the correlation between current GHG emissions and cumulative CO_2 emissions since 1850 is not so high that these two indicators can be used in the analysis. Besides, the results of KMO is 0.500 and significance of Barlett's test is smaller than 0.05 (Table A- 10 in Appendix), which means that PCA can be applied for these two indicators. According to PCA results, there is only one principal component whose eigenvalue is greater than 1.0, explaining 89.15% of the total variation in the analysis (Table 4-2). When only one principal component is found, indicators in the dimension index can be accepted as equal weighted indicators (Gomez-Limon & Riesgo, 2008; Reisi et al., 2014). Similarly, in this study, only one principal component is determined, so both current GHG emissions and cumulative CO_2 emissions since 1850 have the same weight as 0.5.

Table 4-2: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.783	89.150	89.150	1.783	89.150	89.150
2	0.217	10.850	100.000			

Extraction Method: Principal Component Analysis.

4.1.1.2 CBDR - Emission Intensity Dimension Index

Similar to emission level dimension index, before creating emission intensity dimension index, weight of each indicators is needed to be determined. Correlation analysis and KMO test are conducted. Table 4-3 presents the correlation matrix results of six selected indicators. According to this, none of the indicators are highly correlated. Results of KMO is 0.507, and Barlett's test is smaller than 0.05 (Table A- 11 in Appendix), which means that PCA can be applied for these indicators. Table 4-4, presenting PCA results lists that there are three principal components with eigenvalues greater than 1.0. These components explain 86.9 % of the total variation.

Table 4-3: Correlation Matrix of Emission Intensity Indicators

	GHG/cpt	Δ(GHG/cpt)	GHG/GDP	Δ(GHG/GDP)	CONS.CO_2/cpt	Sec.GHG/cpt
GHG/cpt	1.000					
Δ(GHG/cpt)	-0.145	1.000				
GHG/GDP	0.332	0.216	1.000			
Δ(GHG/GDP)	0.125	0.357	0.045	1.000		
Cons.CO_2/cpt	0.814	-0.296	-0.126	0.042	1.000	
Sec.GHG/cpt	0.871	-0.015	0.272	0.190	0.676	1.000

Table 4-4: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.675	44.580	44.580	2.675	44.580	44.580	2.649	44.147	44.147
2	1.528	25.469	70.049	1.528	25.469	70.049	1.369	22.814	66.961
3	1.012	16.867	86.916	1.012	16.867	86.916	1.197	19.954	86.916
4	0.527	8.788	95.704						
5	0.209	3.480	99.184						
6	0.049	0.816	100.000						

Extraction Method: Principal Component Analysis.

With regards to equation-4, to determine the weights of indicators in the emission intensity dimension index, rotated component matrix and explanation of each eigenvalue ratio are needed. As presented in Table 4-4, there are three components with eigenvalues explaining 44.58%, 25.47% and 16.87% of total variance. The other parameter is the factor loadings, reported in Table 4-5. They are listed for each principal component.

Table 4-5: Rotated Component Matrix, Factor Loadings

	Component		
	1	2	3
GHG/cpt	0.957	-0.014	0.220
ΔGHG/cpt	-0.230	0.753	0.330
GHG/GDP	0.134	0.057	0.955
ΔGHG/GDP	0.179	0.877	-0.134
Cons.CO_2/cpt	0.906	-0.118	-0.257
Sec.GHG/cpt	0.899	0.122	0.211

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

As explained in the methods part, weights are calculated by using factor loading of each indicator within the components and then divided by corresponding eigenvalues of the component.

$$W_{kj} = \frac{(factor\ loading_{kj})^2}{eigenvalue_j} \tag{4}$$

Thus, the results of each indicator's weights are presented in Table 4-6. As it can be seen in the table, each indicator has different weights.

Table 4-6: Weights of Emission Intensity Indicators in Each Component

	W-1	W-2	W-3
GHG/cpt	0.343	0.001	0.048
Δ(GHG/cpt)	0.019	0.371	0.107
GHG/GDP	0.007	0.002	0.901
Δ(GHG/GDP)	0.012	0.503	0.018
Cons.CO_2/cpt	0.307	0.009	0.065
Sec.GHG/cpt	0.302	0.010	0.044

After obtaining weights for each indicator (Table 4-6), intermediate dimension indicators are created by multiplying weights and normalized indicators (equation-3). Then, dimension index is created by multiplying intermediate dimension indicators with weights of each components (equation-5). The scores of each dimension indices are listed for 50 countries in Table 4-10.

4.1.1.3 Overall Index for CBDR

As explained above, the overall CBDR index is based on two dimensions. The first dimension is related to emission level and the second is about emission intensity. In order to calculate the weights of each dimension index in the CBDR index, PCA is applied. Similar to conducted PCA procedure for dimension indices, before applying PCA, correlation analysis and KMO and Barlett's tests are also applied to the CBDR overall index. Table 4-7 presents the correlation matrix results of two dimension indices. According to the correlation analysis, both are not correlated.

Table 4-7: Correlation Matrix of Dimension Indices

	Emission Level Dimension	Emission Intensity Dimension
Emission Level Dimension	1.000	
Emission Intensity Dimension	0.294	1.000

After checking the correlation, KMO and Barlett's sphericity tests are applied in order to determine the suitability for PCA. Results of KMO is 0.500, and Barlett's test is smaller than 0.05 (0.039), so PCA can be used for these indicators (Table A- 12 in Appendix). In order to determine the weights of emission level and emission intensity dimension indices in CBDR index, the number of principal components are investigated. The rule is the same as the dimension indices that is any components whose eigenvalues are greater than 1.0 are accepted as a principal component. According to PCA results, there is only one principal component whose eigenvalue is greater than 1.0 explaining 64.7% of total variation (Table 4-8). Since only one principal component is determined in the analysis, two dimension indices are needed to weight equally (Gomez-Limon & Riesgo, 2008; Reisi et al., 2014).

Table 4-8: Number of Principal Components and Eigenvalues

Total Variance Explained						
Comp.	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.294	64.678	64.678	1.294	64.678	64.678
2	0.706	35.322	100.000			

Thus, emission level and emission intensity dimension indices have equal weights as 0.5. Table 4-9 summarizes the first method's CBDR index weights and KMO test results. According to the results, all selected indicators for dimension indices and, findings of dimension index scores for CBDR are appropriate to use PCA. The emission level dimension index has only one component so indicators in the emission level dimension index are weighted equally. The emission intensity dimension index has three components, and indicators in the emission intensity have different weights based on the PCA results. Finally, CBDR index has only one principal component, so emission level and emission intensity dimension indices are equally weighted in order to calculate CBDR scores.

Table 4-9: Weights of indicators and dimension indices based on combined PCA

Dimension	KMO	Indicators	Weights PC-1	Weights PC-2	Weights PC-3
Emission Level	0.500	GHG Emissions	0.500	-	-
		Cumulative CO_2 (1850)	0.500	-	-
Emission Intensity	0.507	GHG/cap	0.343	0.001	0.048
		Change	0.019	0.371	0.107
		GHG/GDP	0.007	0.002	0.901
		Change	0.012	0.503	0.018
		Cons. CO_2/cap	0.307	0.009	0.065
		Sec.GHG/cap	0.302	0.010	0.044
CBDR	0.500	$I_{Emission\ Level}$	0.500	-	-
		$I_{Emission\ Intensity}$	0.500	-	-

Table 4-10 presents CBDR index. According to the results, the USA and China have the highest CBDR index score among selected countries. This means that these two countries should have higher responsibilities to mitigate GHG emissions. Although China is a non-Annex I country to the UNFCCC, China should take emission mitigation responsibility with regard to CBDR index score among 50 mostly emitting countries. Latvia, Philippines and Romania have the lowest CBDR index scores, whereas Latvia and Romania are both Annex-I countries with a lower responsibility level than others. Thus, these results indicate that whatever country groups in the UNFCCC, it is needed to revise countries' responsibilities in the UNFCCC.

Table 4-10: Ranking of Countries According to CBDR Index

Rank	Country	Em. Level	Country	Em. Intensity	**Country**	**CBDR**[7]
1	USA	0.844	Australia	0.723	**USA**	**0.736**
2	China	0.685	Saudi Ar.	0.67	**China**	**0.564**
3	Russia	0.258	Canada	0.629	**Australia**	**0.386**
4	India	0.173	USA	0.627	**Russia**	**0.380**
5	Germany	0.164	S. Korea	0.566	**Saudi Ar.**	**0.354**
6	Japan	0.133	Estonia	0.562	**Canada**	**0.352**
7	UK	0.128	N. Zealand	0.512	**S. Korea**	**0.308**
8	Canada	0.075	Russia	0.502	**Estonia**	**0.282**
9	France	0.074	Israel	0.496	**N. Zealand**	**0.259**
10	Brazil	0.072	Finland	0.477	**Japan**	**0.256**
11	Mexico	0.055	South Afr.	0.467	**South Afr.**	**0.255**
12	Italy	0.054	Malaysia	0.458	**Israel**	**0.251**
13	Indonesia	0.054	China	0.442	**Germany**	**0.242**
14	Poland	0.053	Argentina	0.438	**Finland**	**0.242**
15	S. Korea	0.051	Belgium	0.399	**Malaysia**	**0.238**
16	Australia	0.049	Singapore	0.394	**Argentina**	**0.233**
17	South Afr.	0.043	Greece	0.392	**Belgium**	**0.211**
18	Saudi Arabia	0.038	Japan	0.379	**Mexico**	**0.210**
19	Spain	0.035	Ireland	0.379	**Greece**	**0.201**
20	Turkey	0.029	Netherland	0.373	**Singapore**	**0.200**
21	Argentina	0.028	Czech Rep	0.371	**Netherland**	**0.199**
22	Netherland	0.025	Mexico	0.365	**UK**	**0.199**
23	Thailand	0.024	Portugal	0.364	**Czech Rep**	**0.196**
24	Belgium	0.022	Slovenia	0.355	**India**	**0.195**
25	Czech Rep	0.022	Austria	0.354	**Ireland**	**0.192**
26	Malaysia	0.019	Thailand	0.344	**Italy**	**0.191**
27	Romania	0.017	Norway	0.343	**Portugal**	**0.185**
28	Austria	0.011	Denmark	0.336	**Thailand**	**0.184**
29	Philippines	0.011	Italy	0.327	**Brazil**	**0.183**
30	Greece	0.01	Turkey	0.325	**Austria**	**0.183**
31	Hungary	0.009	Germany	0.321	**Slovenia**	**0.178**
32	Sweden	0.009	Spain	0.317	**France**	**0.177**
33	Finland	0.008	Poland	0.296	**Turkey**	**0.177**
34	Denmark	0.008	Brazil	0.294	**Spain**	**0.176**
35	Bulgaria	0.008	Iceland	0.291	**Poland**	**0.174**
36	Israel	0.007	Bulgaria	0.284	**Norway**	**0.174**
37	Chile	0.007	France	0.281	**Denmark**	**0.172**
38	Portugal	0.006	Malta	0.28	**Indonesia**	**0.151**
39	Switzerland	0.006	UK	0.271	**Bulgaria**	**0.146**
40	Slovakia	0.006	Switzerland	0.258	**Iceland**	**0.145**
41	N. Zealand	0.005	Chile	0.256	**Malta**	**0.140**
42	Singapore	0.005	Indonesia	0.249	**Switzerland**	**0.132**
43	Ireland	0.005	Hungary	0.238	**Chile**	**0.132**
44	Norway	0.005	Slovakia	0.22	**Hungary**	**0.124**
45	Estonia	0.003	India	0.217	**Slovakia**	**0.113**
46	Slovenia	0.002	Sweden	0.207	**Sweden**	**0.108**
47	Lithuania	0.002	Lithuania	0.205	**Lithuania**	**0.104**
48	Latvia	0.001	Romania	0.181	**Romania**	**0.099**
49	Iceland	0.001	Philippines	0.179	**Philippines**	**0.095**
50	Malta	0.001	Latvia	0.178	**Latvia**	**0.089**

[7] $I_{CBDR} = 0.5\ I_{Emission\ Level} + 0.5\ I_{Emission\ Intensity}$

Figure 4-1 shows the emission level and emission intensity dimensions. In terms of emission level, there is a significant gap between top-2 emitters (namely the USA and China) and others. On the other hand, the results of emission intensity dimension index are different than that of emission level. For instance, Australia has the highest emission intensity index; Saudi Arabia, the USA and Canada following Australia. Therefore, there is a difference between countries' emission level and emission intensity conditions. This figure also shows that between countries, there is more divergence in terms of the emission level index than the emission intensity index.

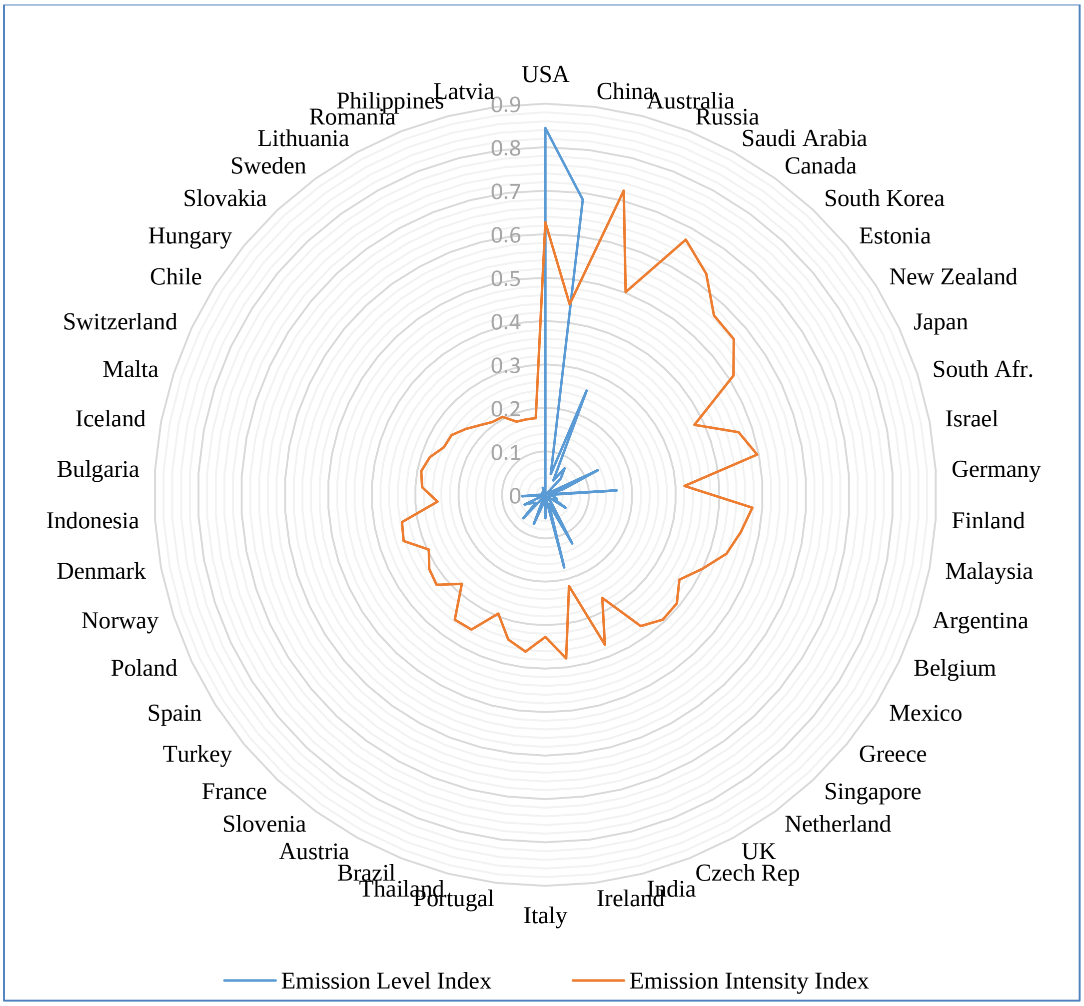

Figure 4-1: Emission Level and Emission Intensity Dimensions of CBDR

In order to group the countries according to CBDR index scores, the Cluster Analysis technique is used. The CLA results and its dendogram in Appendix (Figure A- 3) suggest that there should be five groups. Countries in Group-A are the most responsible countries, and countries in Group-E are the least responsible countries among these 50 countries. This grouping also shows that many Annex-I countries are less responsible than many non-Annex countries. For instance, in Group-E, there are 13 countries and 10 of them are in Annex-I of the UNFCCC. On the other hand, some non-Annex I countries such as China (Group-A), Saudi Arabia (Group-B), South Korea, South Africa, Israel, Malaysia and Argentina (Group-C) have greater responsibility than many Annex-I countries in Table 4-11.

Table 4-11: Clustering Countries According to CBDR Index Scores

Group-A	**Group-B**	**Group-C**	**Group-D**	**Group-E**
USA	Australia	South Korea	Belgium	Indonesia
China	Russia	Estonia	Mexico	Bulgaria
	Saudi Arabia	New Zealand	Greece	Iceland
	Canada	Japan	Singapore	Malta
		South Afr.	Netherland	Switzerland
		Israel	UK	Chile
		Germany	Czech Rep	Hungary
		Finland	India	Slovakia
		Malaysia	Ireland	Sweden
		Argentina	Italy	Lithuania
			Portugal	Romania
			Thailand	Philippines
			Brazil	Latvia
			Austria	
			Slovenia	
			France	
			Turkey	
			Spain	
			Poland	
			Norway	
			Denmark	

According to Figure 4-2, there is no clear distinction between Annex-I and non-Annex I countries of the UNFCCC with regards to CBDR index. Many Annex-I countries' CBDR index is lower than that of some of the non-Annex I countries. In terms of political economy, the argument of North-South division can be seen more clearly in the Southern part of the world. As explained in Chapter Two, the North-South dialogue differentiation proposal has theoretically tried to include all developed (Northern) and developing (Southern) countries for emission reduction concerning their cumulative emissions, per capita emissions, emission growth rate and emission intensity. This map is also an indication of the North-South division through CBDR index. All of the Southern countries except China and Saudi Arabia have low responsibility. Additionally, because the levels of responsibility in the Southern countries are not the same, so differentiation among the Southern countries is also necessary to ensure justice during emission mitigation. Although Saudi Arabia is not as big an emitter as others, it has a high CBDR index. The reason for this is that Saudi Arabia does not consider its emission intensity and rising emission level. Besides, Saudi Arabia, as an oil producing and exporting country, is not concerned with reducing the use of fossil fuels. Other country groups in the South, such as ones with emerging economies or newly industrialized countries should be also separated as developing countries. The Northern countries also need to be differentiated, because they are not convergent with regards to CBDR index. For instance, there is not the same level of responsibility among the OECD member states. Although big emitters such as the USA, China, Russia, Canada and Australia have a darker red color, the European countries are different than other big emitters as it can be seen in the map. Because the European countries have made a significant improvement in emission intensity and emission reduction, they are not as responsible as other Northern countries.

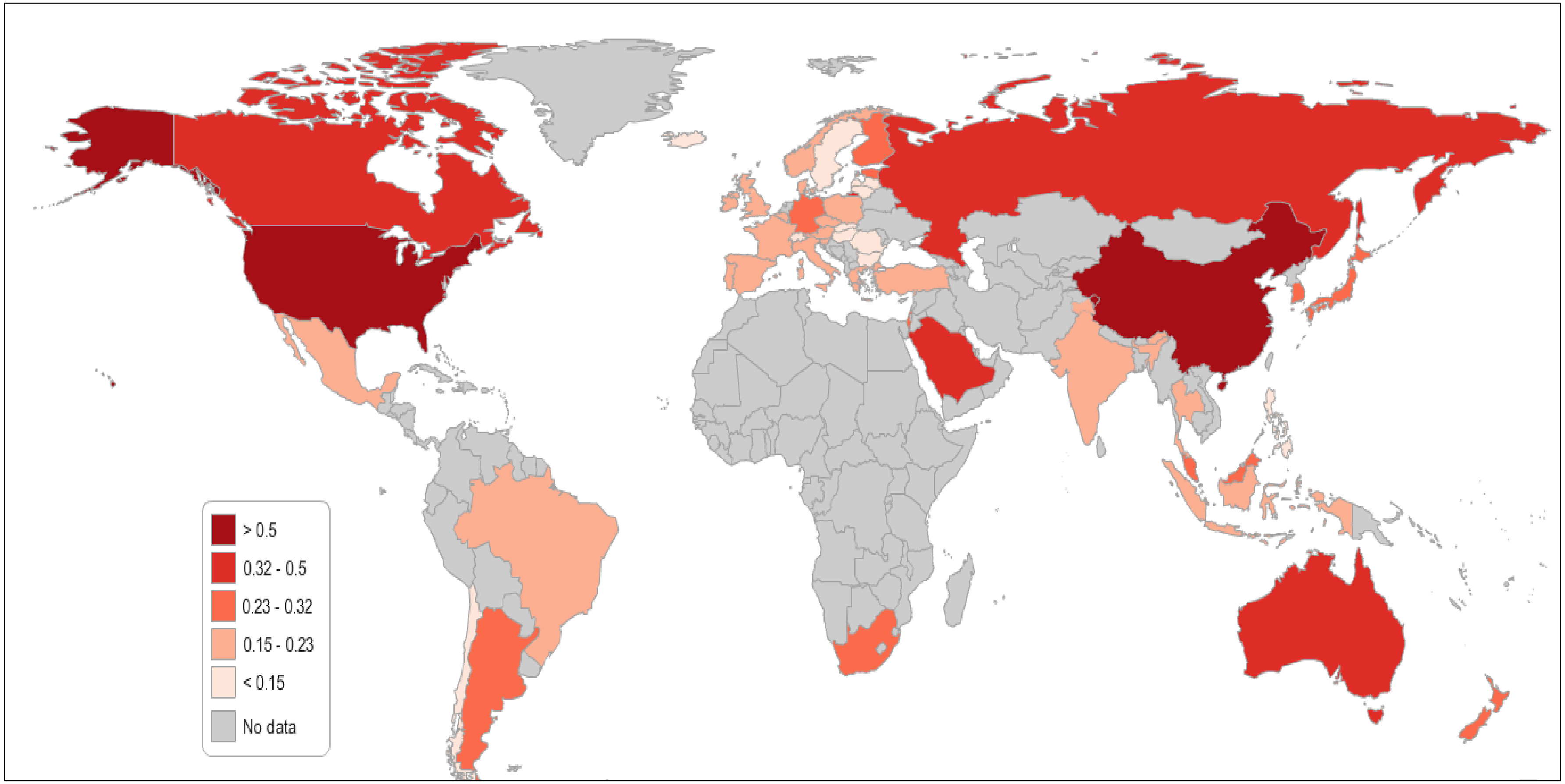

Figure 4-2: World Map based on Method 1 CBDR Index

4.1.2 Creating the Respective Capabilities (RC) Index

RC Index consists of three dimensions, namely economic, social and technical capabilities (Table 4-12). The followed steps of creating RC index are the same as CBDR index.

Table 4-12: Dimensions and Indicators of RC

Overall Index	Dimension Index	Indicators
RC	Economic	GDP
		Per capita GDP
		Gross savings
	Social	Literacy rate
		Unemployment rate
		Gini Coefficient (Income inequality)
		Poverty rate
		Secondary School Enrolment
		Number of hospital bed
	Technical	Patent Numbers
		Share of High Technological Export
		Research and Development
		Share of Renewable Energy

4.1.2.1 Economic Capabilities Dimension Index

In order to create economic capabilities dimension index, GDP, per capita GDP and gross savings are selected for economic capabilities of countries. Before construction of dimension index and determination of the weight of each indicator, correlation analysis and KMO test for PCA are conducted. Table 4-13 presents the correlation matrix results of three indicators. According to this, there is no high correlation among indicators. Thus, all three indicators can be used in the economic capability analysis.

Table 4-13: Correlation Matrix of Economic Indicators

	GDP	GDP/cpt	Gross savings
GDP	1.000		
GDP/cpt	-0.019	1.000	
Gross savings	0.203	-0.032	1.000

The result of KMO is 0.504, but the Barlett's test is higher than 0.05 (0.565), so PCA cannot be applied for these indicators. Therefore, all three indicators are considered as equally weighted.

Table 4-14: KMO and Barlett's Test

KMO Measure of Sampling Adequacy.		0.504
Bartlett's Test of Sphericity	Approx. Chi-Square	2.036
	df	3
	Sig.	0.565

4.1.2.2 RC - Technical Capabilities Dimension Index

For creating technical capabilities dimension index, research and development expenditures (% of GDP), number of patents, ability and capability to manufacture high technologies (% of manufactured industry) and the share of renewable energy sources are used. Before developing dimension index and determination of the weight of each indicator, correlation analysis and KMO test for PCA are conducted. Table 4-15 presents the correlation matrix results of four indicators. The correlation analysis results show that none of the indicators are highly correlated. Results of KMO is 0.512, and Barlett's test is smaller than 0.05, so PCA can be used for these indicators (Table A- 14 in Appendix). Table 4-16 reports the principal components. There are two principal components with eigenvalues greater than 1.0, and they explain 63.8 % of the total variation.

Table 4-15: Correlation Matrix of Technical Indicators

	Renewable	R&D	Patent numbers	High.Tech
Renewable	1.000			
R&D	0.008	1.000		
Patent numbers	-0.051	0.500	1.000	
High.Tech	-0.016	0.079	0.150	1.000

Table 4-16: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.550	38.753	38.753	1.550	38.753	38.753	1.546	38.662	38.662
2	1.004	25.094	63.847	1.004	25.094	63.847	1.007	25.185	63.847
3	0.955	23.872	87.719						
4	0.491	12.281	100.000						

Extraction Method: Principal Component Analysis.

Besides the number of principal components with their respected explanation ratio of eigenvalues, factor loading of each components are also needed. Factor loading of each indicator (w_{kj}) for each principal components are listed in Table 4-17.

Table 4-17: Rotated Component Matrix[a] Factor Loadings

	Component	
	1	2
Renewable	0.003	0.973
R&D	0.838	0.089
Patent numbers	0.855	-0.054
High.Tech	0.336	-0.224

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization.[a]

As explained in the previous chapter, the weights of each indicator are calculated by squared factor loading of each indicator for each principal component divided by corresponding eigenvalues (equation-4). Thus, the weights of each indicator for each principal component are in Table 4-18. As shown in the table, each indicator has different weights in both principal components.

Table 4-18: Weights of Technical Indicators

	W-1	W-2
Renewable	0.001	0.943
R&D	0.453	0.008
Patent Numbers	0.471	0.003
High.Tech	0.073	0.050

Thus, the technical dimension index is created by multiplying weights and intermediate dimension indicators (equation-5). The scores of technical dimension index for each country are given in Table 4-26.

4.1.2.3 RC - Social Capabilities Dimension Index

For creating social dimension index, literacy rate, unemployment rate, Gini coefficient of income inequality, poverty rate, secondary school enrollment rate, and number of hospital beds per 10,000 people are used. Before developing dimension index and determination of the weight of each indicator, correlation analysis and KMO test are conducted. Table 4-19 presents the correlation matrix results of six indicators. According to the correlation analysis, none of the indicators are highly correlated. After completion of correlation analysis, KMO and Barlett's sphericity tests are applied in order to decide the convenience for PCA. Results of KMO is 0.592, and Barlett's test is smaller than 0.05, so PCA can be used for these indicators (Table A-15 in Appendix). According to PCA investigation, there are two principal components with eigenvalues greater than 1.0, and explain 59.8 % of the total variation.

Table 4-19: Correlation Matrix of Social Indicators

	Literacy	Hos.bed	Unemployment	Gini	Sec.Enrol	Poverty
Literacy	1.000					
Hos.bed	0.406	1.000				
Unemployment	-0.156	0.030	1.000			
Gini Coefficient	0.204	0.343	0.101	1.000		
Sec.Enrol	0.521	0.202	-0.212	0.382	1.000	
Poverty	0.411	0.160	0.203	0.351	0.362	1.000

Table 4-20: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.353	39.215	39.215	2.353	39.215	39.215	2.329	38.816	38.816
2	1.233	20.551	59.765	1.233	20.551	59.765	1.257	20.950	59.765
3	0.880	14.664	74.429						
4	0.747	12.447	86.876						
5	0.459	7.656	94.533						
6	0.328	5.467	100.000						

In order to determine the weights of each indicator in the dimension index, rotated component matrix (factor loading) and the percentage of variance explanation of each component are required. Table 4-21 presents the factor loading of each indicators for each principal components.

Table 4-21: Rotated Component Matrix[a] (Factor Loadings)

	Components	
	1	2
Literacy	0.721	-0.379
Hos.bed	0.588	-0.009
Unemployment	0.089	0.912
Gini Coefficient	0.683	0.209
Sec.Enrol	0.697	-0.415
Poverty	0.709	0.257

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

The weights for each indicator are calculated by squared factor loading of each indicator within the components divided by corresponding eigenvalues of the component (equation-4). Thus, the weights of each indicator for each principal components are presented in Table 4-22. As shown, each indicator has different weights.

Table 4-22: Weights of Social Indicators

	W-1	W-2
Literacy Rate	0.221	0.116
Number of Hospital bed	0.147	0.001
Unemployment	0.003	0.675
Gini Coefficient	0.198	0.035
Sec. School Enrolment	0.206	0.140
Poverty Rate	0.214	0.053

The social dimension index is created by multiplying of weights and intermediate dimension indicators (equation-5). The scores of social dimension index are given in Table 4-26.

4.1.2.4 Overall Index for Respective Capabilities

Three dimensions of RC index are analyzed in this study, namely economic, social and technical capabilities. According to the results, a country with high RC Index means that they are more capable to solve global climate change problems particularly mitigation of GHG emissions. High RC Index countries can also assist other vulnerable countries in terms of providing finance, technology transfer, and capacity building in the context of climate change. Before creating RC index and determination of the weight of each dimension index, correlation analysis and KMO test for PCA are conducted. Table 4-23 presents the correlation matrix results of three dimension indices.

Table 4-23: Correlation Matrix of Dimension Indices

	Economic	Social	Technical
Economic	1.000		
Social	0.372	1.000	
Technical	0.332	0.536	1.000

Results of KMO is 0.634, and Barlett's test is smaller than 0.05, so PCA can be used (Table A- 16 in Appendix). According to the PCA, there is only one principal component and it explains 61.1 % of total variation (Table 4-24).

Table 4-24: Number of Principal Components and Eigenvalues

Comp.	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.834	61.135	61.135	1.834	61.135	61.135
2	0.705	23.488	84.623			
3	0.461	15.377	100.000			

Since, only one principal component is determined to explain RC index, the weights of each dimension index should be considered equally (Gomez-Limon & Riesgo, 2008; Reisi et al., 2014). Therefore, economic, social and technical capability dimension indices have equal weights. Table 4-25 summarize RC index weights and KMO test results. All selected indicators for dimension indices and findings of dimension index scores for RC are appropriate to use PCA. The economic dimension index has only one component so indicators are equally weighted. The technical dimension index has two components and each used indicator has different weights based on the PCA results. Similarly, the social dimension index has two components with different weights. Overall RC index has one principal component so three dimension indices are equally weighted in order to calculate RC scores.

Table 4-25: Weights of indicators and dimension indices based on combined PCA

Dimension	KMO	Indicators	Weights on PC-1	Weights on PC-2
Economic	0.504	GDP	0.333	
		GDP/cap	0.333	
		Gross Savings	0.333	
Technical	0.512	Renewable	0.001	0.943
		R&D	0.453	0.008
		Patent #	0.471	0.003
		High Tech.	0.007	0.050
Social	0.592	Literacy	0.221	0.116
		Hos. Bed	0.147	0.001
		Unemployment	0.003	0.675
		Gini Coefficient	0.198	0.035
		Sec. School Enrol.	0.206	0.140
		Poverty	0.214	0.053
RC	0.634	$I_{Economic}$	0.333	
		$I_{Technical}$	0.333	
		I_{Social}	0.333	

Table 4-26 presents the dimension indices and RC Index. In terms of RC index, Japan, Norway, Singapore, Iceland and the USA have higher RC Index scores. So they are highly capable to mitigate their emissions and combat climate change. Bulgaria, Turkey, Greece, Mexico and South Africa have lower RC index scores so their capability is less than other selected countries in this study.

Table 4-26: Ranking of Countries According to RC Index

	Country	Econ.	Country	Soc.	Country	Tech.	Country	RC I.
1	USA	0.678	Australia	0.853	Iceland	0.632	Japan	**0.589**
2	Singapore	0.652	Norway	0.842	Japan	0.533	Norway	**0.583**
3	China	0.628	Japan	0.823	South Korea	0.508	Singapore	**0.575**
4	Norway	0.539	Iceland	0.809	New Zealand	0.430	Iceland	**0.555**
5	Saudi Arabia	0.508	Finland	0.809	Finland	0.404	USA	**0.547**
6	Switzerland	0.445	Austria	0.804	Israel	0.397	South Korea	**0.544**
7	Germany	0.418	Netherlands	0.8	Sweden	0.396	Sweden	**0.515**
8	Japan	0.411	Germany	0.778	Norway	0.367	Australia	**0.509**
9	Netherlands	0.393	New Zealand	0.778	Singapore	0.341	Switzerland	**0.504**
10	South Korea	0.391	Denmark	0.776	Austria	0.329	Finland	**0.504**
11	Sweden	0.381	Sweden	0.767	USA	0.328	Austria	**0.502**
12	Australia	0.381	Belgium	0.763	Denmark	0.312	Germany	**0.487**
13	Austria	0.374	Switzerland	0.761	Switzerland	0.305	China	**0.482**
14	Canada	0.365	France	0.753	Canada	0.302	New Zealand	**0.478**
15	Belgium	0.337	South Korea	0.735	Australia	0.292	Denmark	**0.475**
16	Denmark	0.336	Singapore	0.732	Brazil	0.274	Canada	**0.462**
17	Russia	0.335	Slovenia	0.726	Germany	0.265	Netherlands	**0.457**
18	France	0.326	Czech Rep	0.724	Philippines	0.244	France	**0.435**
19	India	0.315	Hungary	0.718	France	0.226	Belgium	**0.422**
20	UK	0.308	Canada	0.717	Slovenia	0.215	Israel	**0.417**
21	Malaysia	0.307	Malta	0.714	China	0.204	Slovenia	**0.403**
22	Finland	0.299	Romania	0.712	Portugal	0.202	Russia	**0.390**
23	Italy	0.296	Russia	0.709	Latvia	0.200	Czech Rep	**0.384**
24	Ireland	0.292	Poland	0.700	Indonesia	0.196	Ireland	**0.384**
25	Spain	0.29	Estonia	0.695	Estonia	0.19	UK	**0.383**
26	Czech Rep	0.271	Ireland	0.694	Italy	0.186	Estonia	**0.380**
27	Slovenia	0.268	Lithuania	0.682	Netherlands	0.177	Italy	**0.379**
28	Estonia	0.256	UK	0.672	India	0.169	Saudi Arabia	**0.368**
29	Indonesia	0.247	Thailand	0.669	UK	0.168	Hungary	**0.360**
30	Thailand	0.244	Italy	0.654	Belgium	0.166	Latvia	**0.357**
31	Slovakia	0.244	Latvia	0.65	Ireland	0.166	Malaysia	**0.353**
32	Israel	0.235	Slovakia	0.637	Czech Rep	0.157	Indonesia	**0.346**
33	Hungary	0.232	USA	0.634	Spain	0.153	Thailand	**0.345**
34	New Zealand	0.225	Israel	0.618	Malaysia	0.152	Brazil	**0.345**
35	Mexico	0.225	China	0.615	Chile	0.139	Romania	**0.345**
36	Iceland	0.223	Malaysia	0.602	Hungary	0.132	Malta	**0.339**
37	Latvia	0.222	Saudi Arabia	0.596	Lithuania	0.126	Poland	**0.336**
38	Romania	0.222	Chile	0.596	Russia	0.125	Spain	**0.333**
39	Argentina	0.212	Indonesia	0.595	Thailand	0.123	Lithuania	**0.328**
40	Poland	0.21	Portugal	0.589	South Afr.	0.119	Portugal	**0.325**
41	Chile	0.21	Argentina	0.583	Malta	0.118	Slovakia	**0.323**
42	Brazil	0.196	Bulgaria	0.573	Romania	0.102	Philippines	**0.319**
43	Bulgaria	0.185	Brazil	0.566	Mexico	0.099	Chile	**0.315**
44	Malta	0.184	Turkey	0.558	Poland	0.096	Argentina	**0.291**
45	Portugal	0.184	Spain	0.555	Turkey	0.096	India	**0.288**
46	Lithuania	0.174	Philippines	0.549	Greece	0.087	Bulgaria	**0.278**
47	Philippines	0.162	Greece	0.523	Slovakia	0.086	Turkey	**0.271**
48	Turkey	0.158	Mexico	0.485	Argentina	0.079	Mexico	**0.270**
49	Greece	0.148	India	0.379	Bulgaria	0.078	Greece	**0.252**
50	South Afr.	0.137	South Afr.	0.318	Saudi Arabia	0.001	South Afr.	**0.192**

Figure 4-3 shows each country's different capabilities. In terms of economic capabilities, the USA, Singapore and China are the most capable countries; Australia, Norway and Japan are the most socially capable countries. In conditions of technical capabilities Iceland, Japan and South Korea are the most able ones. Therefore, the champions of each capability are not the same. Results indicate that economic, social and technical capabilities are not similar based on national circumstances. For instance, Iceland has higher social and technical capabilities, but its economic capabilities are low. Similarly, the Netherlands has very high social capability, but its economic and technical capabilities are on average. Thus, this shows that each country has special circumstances which consists of various social, technical and economic capabilities or ability to combat climate change. Therefore, it is necessary to analyze each country carefully in terms of having a receipt and donor country capabilities. While countries are expected to provide financially and technologically to combat climate change, their supports should be based on their specific capabilities.

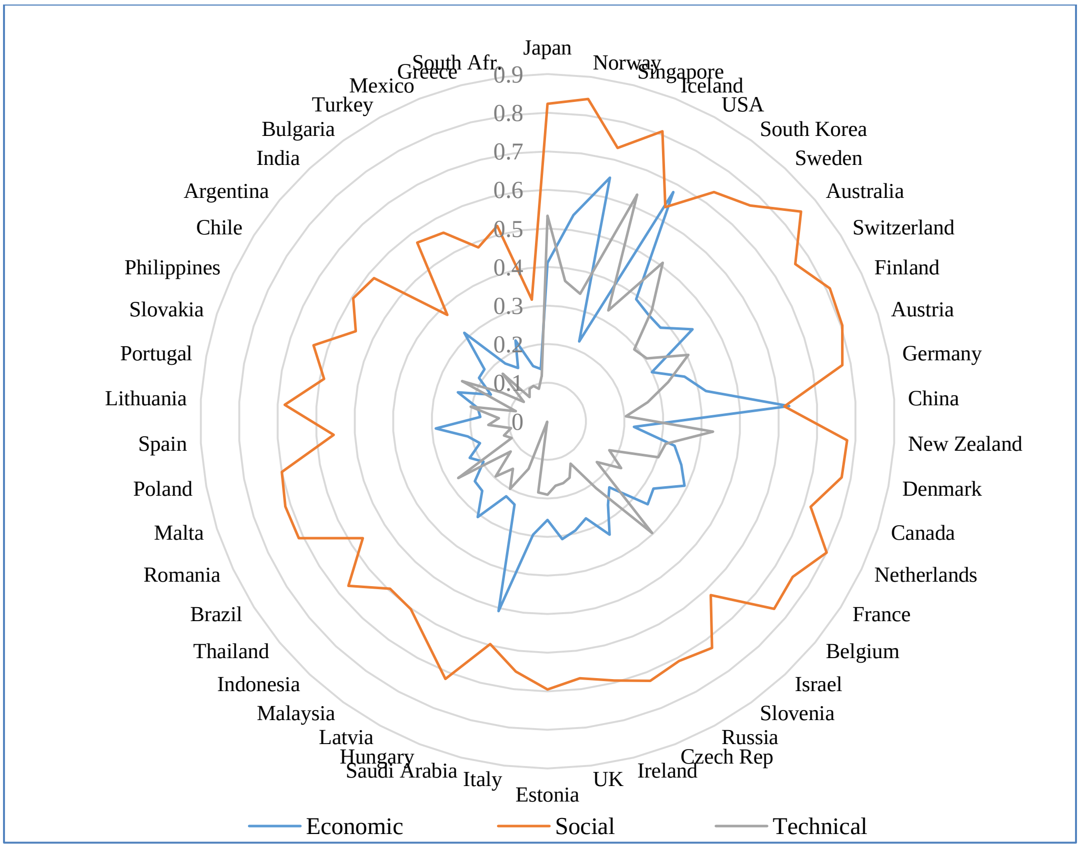

Figure 4-3: Dimension Indices for RC Index

According to the CLA results, there can be five groups for RC index scores (Appendix, Figure A- 4). Countries in Group-A are the most capable countries, and countries in Group-E are the least capable countries. Many Annex-I countries have less capable than non-Annex I countries. In Group-A for instance, there are six countries three of which are not included in Annex-I of the UNFCCC. Thus, these countries should not be eligible to receive financial and technical assistance from developed countries. In Group-E there are seven countries and three of them are Annex-I countries namely Bulgaria, Turkey and Greece. This shows that these three countries should be more eligible for receiving financial and technical assistance than many of non-Annex I countries.

Table 4-27: Clustering Countries According to RC Index Scores

Group-A	Group-B	Group-C	Group-D	Group-E
Japan	Sweden	France	Saudi Arabia	Argentina
Norway	Australia	Belgium	Hungary	India
Singapore	Switzerland	Israel	Latvia	Bulgaria
Iceland	Finland	Slovenia	Malaysia	Turkey
USA	Austria	Russia	Indonesia	Mexico
South Korea	Germany	Czech Rep	Thailand	Greece
	China	Ireland	Brazil	South Africa
	New Zealand	UK	Romania	
	Denmark	Estonia	Malta	
	Canada	Italy	Poland	
	Netherlands		Spain	
			Lithuania	
			Portugal	
			Slovakia	
			Philippines	
			Chile	

Figure 4-4 shows the illustrations of country groups based on RC index scores. All Group-A countries except Singapore and South Korea are in the Annex-I and the Northern countries. In reality, Singapore and South Korea do not resemble to Southern countries, either. This problem is based on the static classification of political economy and current annexes of the UNFCCC. During the preparation of the UNFCCC in the early 1990s, being an OECD member was accepted as a criterion for being an Annex-II lists. As explained earlier, Annex-II countries have additional responsibilities to assist developing countries in terms of finance and technology transfer. However, according to the results of this study, there is also no clear distinction between OECD and non-OECD countries in terms of RC index. In fact, OECD countries' RC index scores are not scattering uniformly. For instance, Mexico (Group-E), Chili (Group-D), South Korea (Group-A), Canada (Group-B) and the UK (Group-C) are all the OECD members, but each of them belong to different RC index group. Similarly, Singapore and South Korea should not be kept out of providing assistance to developing countries. This also shows that being an OECD member cannot be a criterion to classify countries as more capable or responsible.

The other classification problem in the UNFCCC is related to economy in transition countries. Although they are only in Annex-I of the UNFCC, some of their capabilities are lower than that of many non-Annex I countries such as Brazil, China, South Korea, Singapore Thailand, and Chili. Some economy in transition countries such as Latvia, Romania, Poland and Slovakia is the worst of the EU in the context of RC index. This indicates that there is also no convergence among the EU member states. Hence, calling for any group commitments as a whole such as the EU might have certain risks.

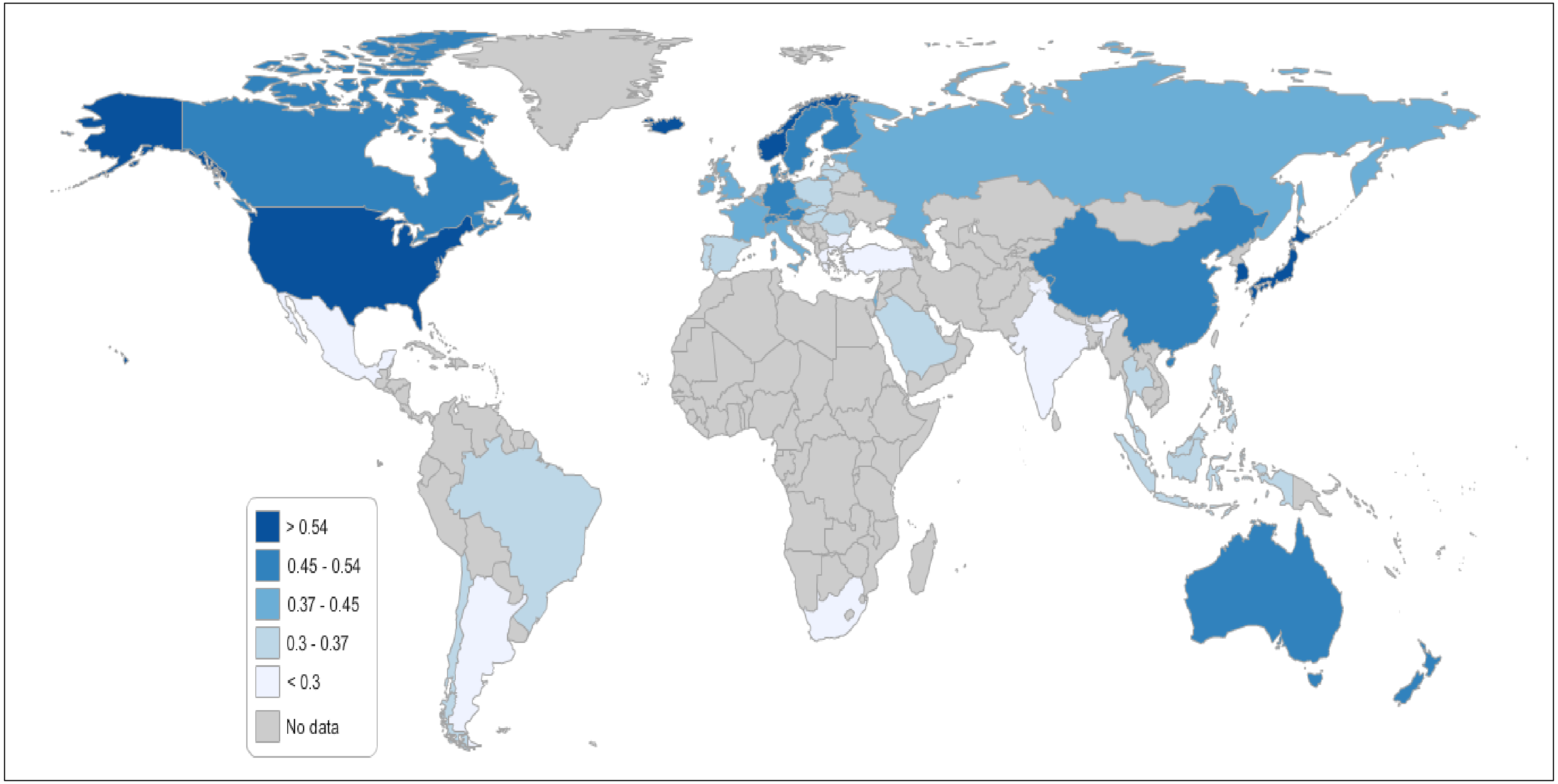

Figure 4-4: World Map based on Method 1 RC Index

Table 4-28: Ranking of Countries According to RC and CBDR Indices

Rank	Country	RC Index	Rank	Country	CBDR Index
1	Japan	0.589	1	USA	0.736
2	Norway	0.583	2	China	0.563
3	Singapore	0.575	3	Australia	0.386
4	Iceland	0.555	4	Russia	0.380
5	USA	0.547	5	Saudi Arabia	0.353
6	South Korea	0.544	6	Canada	0.352
7	Sweden	0.515	7	South Korea	0.308
8	Australia	0.509	8	Estonia	0.282
9	Switzerland	0.504	9	New Zealand	0.258
10	Finland	0.504	10	Japan	0.256
11	Austria	0.502	11	South Afr.	0.255
12	Germany	0.487	12	Israel	0.251
13	China	0.482	13	Germany	0.242
14	New Zealand	0.478	14	Finland	0.242
15	Denmark	0.475	15	Malaysia	0.238
16	Canada	0.462	16	Argentina	0.233
17	Netherlands	0.457	17	Belgium	0.210
18	France	0.435	18	Mexico	0.209
19	Belgium	0.422	19	Greece	0.201
20	Israel	0.417	20	Singapore	0.200
21	Slovenia	0.403	21	Netherlands	0.199
22	Russia	0.390	22	UK	0.199
23	Czech Rep	0.384	23	Czech Rep	0.196
24	Ireland	0.384	24	India	0.194
25	UK	0.383	25	Ireland	0.192
26	Estonia	0.380	26	Italy	0.191
27	Italy	0.379	27	Portugal	0.185
28	Saudi Arabia	0.368	28	Thailand	0.184
29	Hungary	0.360	29	Brazil	0.183
30	Latvia	0.357	30	Austria	0.182
31	Malaysia	0.353	31	Slovenia	0.178
32	Indonesia	0.346	32	France	0.177
33	Thailand	0.345	33	Turkey	0.176
34	Brazil	0.345	34	Spain	0.175
35	Romania	0.345	35	Poland	0.174
36	Malta	0.339	36	Norway	0.174
37	Poland	0.336	37	Denmark	0.172
38	Spain	0.333	38	Indonesia	0.151
39	Lithuania	0.328	39	Bulgaria	0.146
40	Portugal	0.325	40	Iceland	0.145
41	Slovakia	0.323	41	Malta	0.140
42	Philippines	0.319	42	Switzerland	0.132
43	Chile	0.315	43	Chile	0.132
44	Argentina	0.291	44	Hungary	0.123
45	India	0.288	45	Slovakia	0.113
46	Bulgaria	0.278	46	Sweden	0.108
47	Turkey	0.271	47	Lithuania	0.104
48	Mexico	0.270	48	Romania	0.098
49	Greece	0.252	49	Philippines	0.094
50	South Afr.	0.192	50	Latvia	0.089

CBDR and RC indices are two different perspectives of burden sharing for emission mitigation. The CBDR index can be used to allocate emission mitigation responsibilities on the base of equity. The RC Index can be used to determine a country's capability to transfer their certain capacity or well-being for the sake of emission mitigation. While some countries have high CBDR index scores, they may not be good on the RC Index. As shown in the Figure 4-5, CBDR and RC indices are positioned as "x" and "y" axes respectively. The crossing lines represent the average of 50 countries selected for CBDR and RC index scores. There are four regions in the figure. The *first* region represents countries with low RC and CBDR values. Some of these countries are Slovakia, the Philippines, Bulgaria, Greece, Turkey and Chile. These countries are not only less responsible, but also have less capability for emission mitigation. It can be expected that whatever these countries' current classifications in the UNFCCC, these countries' emission mitigation commitments should not exceed the commitments of others. The *second* region with high RC and low CBDR represents less responsible and highly prosperous countries such as Denmark, Sweden, Iceland, Switzerland, and France. These countries do not have to take more emission reduction targets, but they can provide finance and technology transfers to other countries for emission reductions. Because climate change is a common problem, countries in the second region can make contributions in line with their capabilities to solve this problem. The *third* region represents countries with high RC and high CBDR. Some of these countries are the USA, China, Canada, Japan, New Zealand, Israel, Finland, and Germany. They should mitigate their emissions and also assist other countries to reduce their emissions. They also lead in combating climate change. The *fourth* region with low RC and high CBDR represents high responsibility and low prosperity countries such as Russia, Saudi Arabia, Malaysia, Mexico, Argentina, etc. It can be suggested that these countries should be supported in reducing their own emissions by high capable countries. Besides, countries in the fourth region should implement emission reduction activities without compromising their development needs. In terms of the current classification of countries under the UNFCCC, there are no concrete differences between Annex-I and non-Annex I countries. Some non-Annex I countries such as South Korea and Singapore have a higher RC index, and their CBDR index is almost average, but some Annex-I countries such as Bulgaria, Turkey and Greece have low scores at both CBDR and RC. China, a non-Annex I country, has a higher RC index compared to many Annex-I countries, and also has one of the highest CBDR score. Another interesting finding is for South Korea which is not listed in Annex-I; indicating its responsibility and capability indices have higher values than many Annex-I countries. Similar to this, whereas Slovakia is an Annex-I country, and its responsibilities and capabilities are less than many non-Annex I countries. These results indicate that the current classification of the UNFCCC may be out of date and it might be appropriate to revise it.

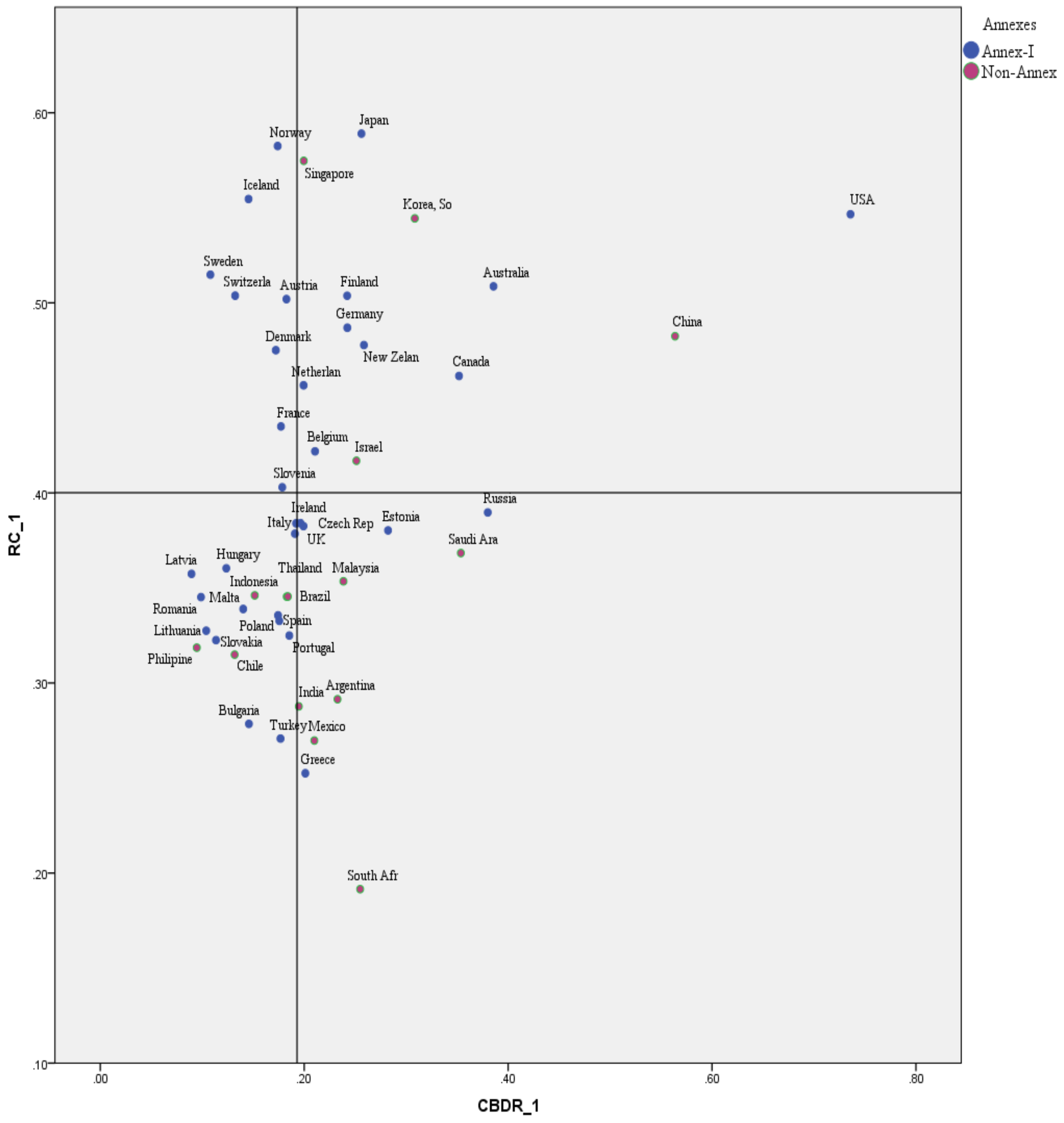

Figure 4-5: CBDR Index vs. RC Index for Method 1

4.2 Results of Method 2

In this section, CBDR and RC indices are created based on method 2. The dimension index is not conducted in this study. All related indicators are directly used by PCA.

4.2.1 Results for CBDR Index

Total GHG, per capita GHG, change of GHG emissions in per unit, cumulative CO_2 since 1850, cumulative GHG since 1990, consumption based per capita CO_2 emissions and sectoral aggregated per capita GHG are used with this method. Before creating CBDR index correlation and KMO test are checked for PCA. KMO is 0.478 and it is not appropriate to apply PCA (Table A- 17 in Appendix). To solve this problem, highly correlated indicator (cumulative GHG emissions since 1990) is excluded from the analysis. The new results indicate that there are no highly correlated indicators (Table 4-29). Results of KMO is 0.525, and Barlett's test is smaller than 0.05, so PCA can be applied (Table A- 20 in Appendix). In order to determine the number of principal components which are expected to be greater than 1.0 are investigated by PCA. According to PCA results, listed in Table 4-30, there are three principal components, explaining 82.7 % of total variation (Appendix, Figure A- 1).

Table 4-29: Correlation Matrix of CBDR Indicators

	GHG	GHG/GDP	Δ(GHG/GDP)	Cum.CO_2.1850	Cons.CO_2/cpt	Sec.GHG/cpt	GHG/cpt
GHG	1.000						
GHG/GDP	0.391	1.000					
Δ(GHG/GDP)	-0.154	0.045	1.000				
Cum.CO_2.1850	0.783	0.202	-0.112	1.000			
Cons.CO_2/cpt	0.044	-0.126	0.042	0.369	1.000		
Sec.GHG/cpt	0.059	0.272	0.190	0.198	0.676	1.000	
GHG/cpt	0.115	0.332	0.125	0.328	0.814	0.871	1.000

Table 4-30: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.912	41.593	41.593	2.912	41.593	41.593	2.626	37.521	37.521
2	1.764	25.193	66.786	1.764	25.193	66.786	1.957	27.952	65.473
3	1.111	15.870	82.656	1.111	15.870	82.656	1.203	17.184	82.656
4	0.821	11.734	94.390						
5	0.216	3.091	97.482						
6	0.130	1.854	99.335						
7	0.047	0.665	100.000						

Extraction Method: Principal Component Analysis.

In order to find weights of each principal component in the CBDR index, ratio of each eigenvalues to total eigenvalues are calculated (equation-10a). Thus, the weights of each principal component symbolized by "γ" is listed in Table 4-31. The sum of each principal component weights must be 1.0. According to the results, each component has different weights.

Table 4-31: Eigenvalues and γ coefficient of each Principal Components

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

In order to find CBDR index, each principal component is multiplied with corresponding weights (γ) (equation-10a). The dominant variables of the first principal component (*PC-1*) are per capita GHG emissions, consumption based per capita emissions and sectoral per capita emissions (Appendix, Table A- 20). This shows that all the variables are related to per capita emissions, so, the PC-1 represents different aspects of per capita emissions. The leading variables of the second principal component (*PC-2*) are current GHG emissions and cumulative emissions since 1850. Therefore, the component is based on absolute emissions. The dominant variables of the third principal component (*PC-3*) are GHG emissions per unit GDP and change of GHG emissions per unit GDP. This component represents the emission intensity aspects of the countries' economies.

Table 4-32 presents the score of each principal component and CBDR index. The CBDR index score indicates that the USA is the most responsible country and Philippines is the least responsible country for climate change among the 50 countries. Same as method 1's result, the USA still is the most responsible country. Except the small ranking changes, top-10 and bottom - 10 countries of both methods are almost the same. Therefore, these results can be accepted as a robustness testing of the methods.

Table 4-32: CBDR Index Scores for Countries

Rank	Country	PC-1	PC-2	PC-3	CBDR INDEX[8]
1	USA	2.546	4.355	-0.843	2.447
2	Australia	2.670	-0.165	1.084	1.501
3	Canada	1.961	-0.128	0.783	1.098
4	Russia	0.313	1.373	1.621	0.887
5	Saudi Arabia	1.698	-1.055	1.728	0.865
6	China	-1.465	4.389	1.134	0.818
7	Estonia	0.460	-0.498	2.442	0.548
8	New Zealand	0.915	-0.421	1.059	0.535
9	South Korea	0.689	-0.334	0.944	0.426
10	Finland	1.081	-0.489	0.052	0.405
11	Israel	0.870	-0.693	0.634	0.348
12	Ireland	0.910	-0.111	-1.053	0.222
13	South Afr.	-0.460	0.054	1.979	0.165
14	Germany	0.381	0.643	-1.176	0.162
15	Czech Rep	0.321	0.148	-0.312	0.147
16	Belgium	0.756	-0.351	-0.683	0.142
17	Malaysia	0.001	-0.391	1.161	0.104
18	Japan	0.179	0.042	-0.194	0.066
19	Netherlands	0.456	-0.287	-0.466	0.052
20	Singapore	0.782	-0.476	-1.087	0.039
21	Greece	0.425	-0.451	-0.234	0.031
22	Argentina	-0.783	0.068	2.015	0.013
23	UK	0.110	0.583	-1.494	-0.054
24	Norway	0.592	-0.552	-1.120	-0.085
25	Denmark	0.424	-0.368	-0.988	-0.088
26	Poland	-0.344	0.470	-0.529	-0.132
27	Austria	0.283	-0.530	-0.621	-0.138
28	Slovenia	0.014	-0.421	-0.214	-0.163
29	Italy	-0.021	-0.366	-0.392	-0.197
30	Portugal	-0.051	-0.768	0.181	-0.225
31	Iceland	0.106	-0.347	-0.919	-0.229
32	Bulgaria	-0.654	0.208	0.186	-0.230
33	France	-0.188	-0.111	-0.731	-0.269
34	Mexico	-0.662	-0.521	1.104	-0.280
35	Spain	-0.140	-0.433	-0.450	-0.289
36	Slovakia	-0.385	0.111	-1.120	-0.375
37	Malta	-0.279	-0.365	-0.714	-0.389
38	Lithuania	-0.582	0.029	-0.799	-0.437
39	Hungary	-0.572	-0.176	-0.648	-0.466
40	Brazil	-1.190	-0.109	0.822	-0.474
41	Turkey	-0.821	-0.552	0.502	-0.485
42	Switzerland	-0.211	-0.627	-1.081	-0.505
43	Romania	-0.963	0.236	-0.748	-0.556
44	Thailand	-1.198	-0.437	0.853	-0.572
45	Sweden	-0.439	-0.294	-1.405	-0.580
46	Latvia	-0.940	0.017	-0.797	-0.621
47	India	-2.024	0.913	0.164	-0.708
48	Chile	-1.119	-0.362	-0.237	-0.719
49	Indonesia	-1.636	0.012	0.500	-0.723
50	Philippines	-1.817	-0.464	0.107	-1.035

[8] $I_{CBDR} = 0.503\, PC_1 + 0.305\, PC_2 + 0.192\, PC_3$

In order to group the countries based on the scores of CBDR index, Cluster Analysis (CLA) is used (Appendix, Figure A- 5). The results suggest that countries in Group-A have the highest and Group-E delivers the lowest responsibility among all 50 countries to mitigate emissions (Table 4-33). The findings also suggest that the USA's emission mitigation efforts in order to ensure responsibility dimension of equity should be much more than other countries.

Table 4-33: Clustering Countries According to CBDR Index Scores

Group-A	Group-B	Group-C	Group-D	Group-E
USA	Australia	Estonia	UK	Slovakia
	Canada	New Zealand	Norway	Malta
	Russia	Korea, So	Denmark	Lithuania
	Saudi Arabia	Finland	Poland	Hungary
	China	Israel	Austria	Brazil
		Ireland	Slovenia	Turkey
		South Afr.	Italy	Switzerland
		Germany	Portugal	Romania
		Czech Rep	Iceland	Thailand
		Belgium	Bulgaria	Sweden
		Malaysia	France	Latvia
		Japan	Mexico	India
		Netherlands	Spain	Chile
		Singapore		Indonesia
		Greece		Philippines
		Argentina		

The map illustrated in Figure 4-6 presents the distribution of countries based on CBDR index scores. Similar to method 1's findings, there is no appropriate convergence in terms of institutional perspective such as being an OECD member state. Likewise, it is not found out any 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. It is not seen any country in Group A and B from the Southern part of the world. 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.

There is a new group emerging in the same cluster based on the results of both methods. This group includes countries: Canada, Russia, Saudi Arabia and Australia. Results suggest that these countries' CBDR index are close to each other, so they should take similar emission mitigation commitments. All these results show that the current classification based on Annexes or institutional criterion according to the early 1990s cannot be used to determine 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 very likely leads to incorrect classification.

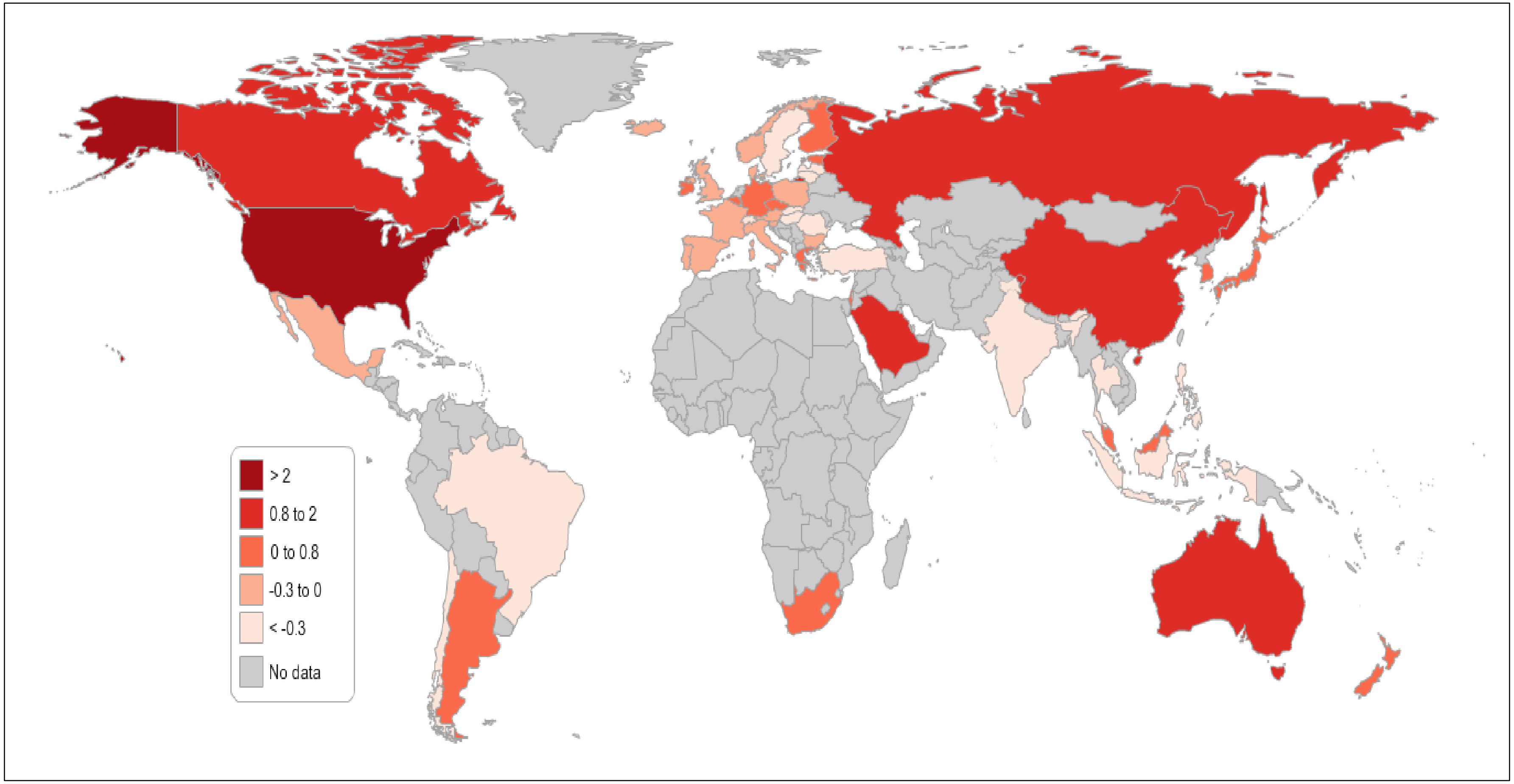

Figure 4-6: World Map Groups based on Method 2 CBDR Index

4.2.2 Results for RC Index

GDP, per capita GDP, percentage of gross savings in the GDP, literacy rate, number of hospital beds, the percentage of R&D expenditure in the GDP, patent numbers, the percentage of high technology products in the total exported manufacturing industry, the unemployment rate, the secondary school enrollment, Gini coefficient of income inequality and poverty rate are used for creating RC index.

Before construction of RC index, correlation analysis and KMO test are conducted for PCA. Table 4-34 presents the correlation matrix results of twelve indicators. According to this, there is no high correlation between indicators. Results of KMO is 0.683, and Barlett's test is smaller than 0.05, so PCA can be used (Table A-22 in Appendix). According to PCA results providing in Table 4-35, there are four principal components explaining 67.67 % of total variation (Appendix, Figure A- 2). The first, second, third and fourth principal component captures 29.9%, 18.3%, 11.0% and 8.5% of the total variation respectively.

Table 4-34: Correlation Matrix of RC Indicators

	GDP	GDP/cpt	Gross.sav	Literacy	Hos.bed	Unempl	Gini	Sec.Enrol	Poverty	R&D	Patent #	High.Tech
GDP	1.000											
GDP/cpt	-0.019	1.000										
Gross.sav	0.203	-0.032	1.000									
Literacy	-0.210	0.418	-0.243	1.000								
Hos.bed	-0.025	0.193	-0.074	0.406	1.000							
Unempl	0.168	0.127	0.519	-0.156	0.030	1.000						
Gini	-0.258	0.406	-0.070	0.204	0.343	0.101	1.000					
Sec.Enrol	-0.233	0.680	-0.273	0.521	0.202	-0.212	0.382	1.000				
Poverty	-0.126	0.490	0.042	0.411	0.160	0.203	0.351	0.362	1.000			
R&D	0.132	0.658	-0.071	0.304	0.372	0.227	0.305	0.397	0.383	1.000		
Patent #	0.208	0.397	0.073	0.166	0.401	0.278	-0.006	0.231	0.222	0.500	1.000	
High.Tech	-0.026	0.120	0.255	0.001	-0.065	0.378	-0.095	-0.054	0.204	0.079	0.150	1.000

Table 4-35: Number of Principal Components and Eigenvalues

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.591	29.923	29.923	3.591	29.923	29.923	3.167	26.393	26.393
2	2.192	18.268	48.191	2.192	18.268	48.191	1.986	16.548	42.941
3	1.320	11.002	59.193	1.320	11.002	59.193	1.517	12.644	55.585
4	1.018	8.480	67.674	1.018	8.480	67.674	1.451	12.089	67.674
5	0.915	7.626	75.300						
6	0.675	5.627	80.927						
7	0.587	4.892	85.819						
8	0.517	4.306	90.124						
9	0.421	3.506	93.631						
10	0.353	2.944	96.575						
11	0.225	1.874	98.449						
12	0.186	1.551	100.000						

In order to determine weights of each principal component in the RC index, ratio of each eigenvalues to total eigenvalues are calculated as shown in equation-10b. The weights of each principal's coefficient shown with "γ" is presented in Table 4-36.

Table 4-36: Eigenvalues and γ coefficient of each Principal Components

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

In order to find RC index, each principal component is multiplied with corresponding weights (γ) as shown equation-10b. Table 4-37 presents the score of each principal components and RC index. The RC index score indicates that Singapore is the most capable and South Africa is the least capable country for climate change among the 50 countries.

Table 4-37: RC Index Scores for Countries

Rank	Country	PC-1	PC-2	PC-3	PC-4	RC Index[9]
1	Singapore	1.915	2.317	0.651	-2.253	1.296
2	Japan	0.501	0.259	2.856	2.749	1.100
3	South Korea	0.536	0.969	2.322	1.029	1.005
4	Norway	1.257	1.289	-0.768	0.120	0.794
5	Australia	1.547	0.207	0.076	-0.037	0.748
6	Switzerland	0.771	1.126	-0.386	0.234	0.612
7	Finland	1.137	0.009	-0.244	0.829	0.569
8	Iceland	1.264	-0.070	-0.212	0.299	0.543
9	Sweden	0.997	0.582	-0.650	0.315	0.532
10	Austria	0.511	0.578	-0.336	1.369	0.499
11	USA	0.453	-0.847	3.907	-0.930	0.490
12	Netherlands	1.069	0.332	-0.498	-0.166	0.461
13	Germany	0.329	0.244	0.410	1.338	0.446
14	New Zealand	1.178	-0.402	0.281	-0.626	0.380
15	Denmark	0.945	0.006	-0.617	0.271	0.353
16	Canada	0.733	0.054	0.216	-0.183	0.351
17	France	0.902	-0.211	0.047	0.005	0.350
18	Israel	0.344	-0.336	1.048	-0.090	0.220
19	Belgium	0.452	-0.178	-0.466	0.864	0.184
20	China	-1.192	1.607	2.112	-0.702	0.162
21	Ireland	1.358	-0.860	-0.659	-1.067	0.127
22	Malaysia	-0.417	2.068	-0.515	-1.687	0.079
23	UK	0.661	-0.419	0.160	-1.033	0.076
24	Czech Rep	-0.087	0.253	-0.535	0.879	0.053
25	Malta	0.395	0.603	-1.187	-0.780	0.047
26	Slovenia	0.065	-0.186	-0.673	1.010	-0.004
27	Russia	-0.806	0.270	0.583	1.274	-0.029
28	Hungary	-0.140	0.100	-1.002	0.899	-0.085
29	Estonia	-0.165	-0.255	-0.557	0.646	-0.151
30	Italy	0.000	-0.745	0.102	0.088	-0.174
31	Thailand	-0.899	1.487	-0.852	-0.628	-0.213
32	Poland	-0.300	-0.570	-0.510	0.726	-0.278
33	Lithuania	-0.055	-0.733	-0.669	0.305	-0.293
34	Romania	-0.959	0.206	-1.017	1.384	-0.360
35	Latvia	-0.318	-0.517	-0.810	0.300	-0.374
36	Philippines	-0.562	0.997	-0.789	-2.336	-0.401
37	Saudi Arabia	-1.439	0.942	-0.566	0.458	-0.417
38	Slovakia	-0.682	-0.643	-0.785	1.200	-0.453
39	Portugal	0.012	-1.524	-0.248	-0.386	-0.495
40	Spain	0.408	-2.118	-0.277	-0.489	-0.498
41	Indonesia	-1.319	0.729	-0.509	-0.326	-0.510
42	Chile	-0.605	-0.347	-0.105	-1.084	-0.514
43	Brazil	-0.729	-0.548	0.553	-1.230	-0.534
44	Argentina	-1.038	-0.500	-0.019	-0.040	-0.602
45	Bulgaria	-0.952	-0.804	-0.112	0.212	-0.629
46	Turkey	-1.071	-0.622	-0.212	-0.138	-0.693
47	Greece	-0.019	-2.296	-0.529	-0.258	-0.747
48	Mexico	-1.594	-0.362	0.543	-0.892	-0.826
49	India	-3.428	1.431	0.561	0.393	-0.989
50	South Afr.	-0.965	-2.573	0.887	-1.834	-1.207

[9] $I_{RC} = 0.442\ PC_1 + 0.267\ PC_2 + \ 0.163\ PC_3 + 0.125\ PC_4$

In order to group countries based on the RC index scores, CLA method is applied. The results suggest that there are five groups (Appendix, Figure A- 6). Counties in Group-A is the most capable ones and countries in Group-E is the least capable country groups. In Group-A, there are five countries and two of them are non-Annex I countries. And in Group-E there are five countries and two of them are Annex-I countries (Turkey and Greece).

Table 4-38: Clustering Countries According to RC Index Scores

Group-A	Group-B	Group-C	Group-D	Group-E
Singapore	Switzerland	Israel	Estonia	Turkey
Japan	Finland	Belgium	Italy	Greece
South Korea	Iceland	China	Thailand	Mexico
Norway	Sweden	Ireland	Poland	India
Australia	Austria	Malaysia	Lithuania	South Afr.
	USA	UK	Romania	
	Netherlands	Czech Rep	Latvia	
	Germany	Malta	Philippines	
	New Zealand	Slovenia	Saudi Arabia	
	Denmark	Russia	Slovakia	
	Canada	Hungary	Portugal	
	France		Spain	
			Indonesia	
			Chile	
			Brazil	
			Argentina	
			Bulgaria	

The world map illustrated in Figure 4-7 illustrates countries' groups 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. Besides, same as the findings of method 1, the EU countries have not same capability level. In terms of institutional perspective, the OECD member states have not resembled 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 the Northern countries. Thus, the results of method 1 and method 2 are similar in terms of both CBDR and RC. It proofs that the current classification based on Annexes and institutional criterion cannot be utilized to determine countries' emission mitigation capabilities.

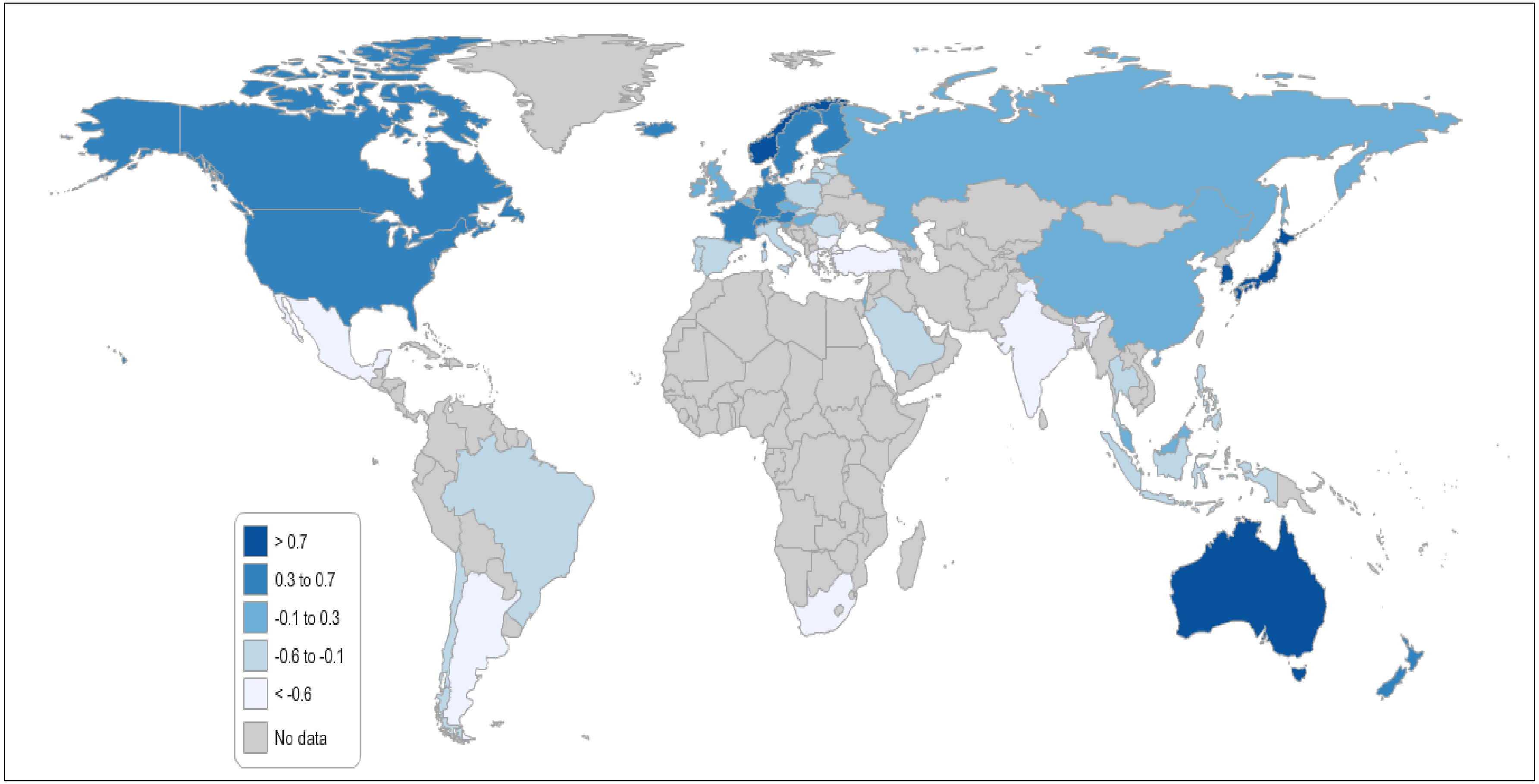

Figure 4-7: Country World Map based on Method-2 RC Index

Figure 4-8 gives similar results with Figure 4-5 for method 1. There are four regions in the figure. Countries in the *first* area with low RC and CBDR index values are not only less responsible, but also have low capability for emission mitigation. Whatever these countries' classifications 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 CBDR 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 CBDR 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 CBDR. 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 combatting climate change. Countries in the fourth area with low RC and high CBDR have high 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 is no concrete differences between Annex-I and non-Annex countries. Thus, there is a need for revisiting the classification of countries in the UNFCCC.

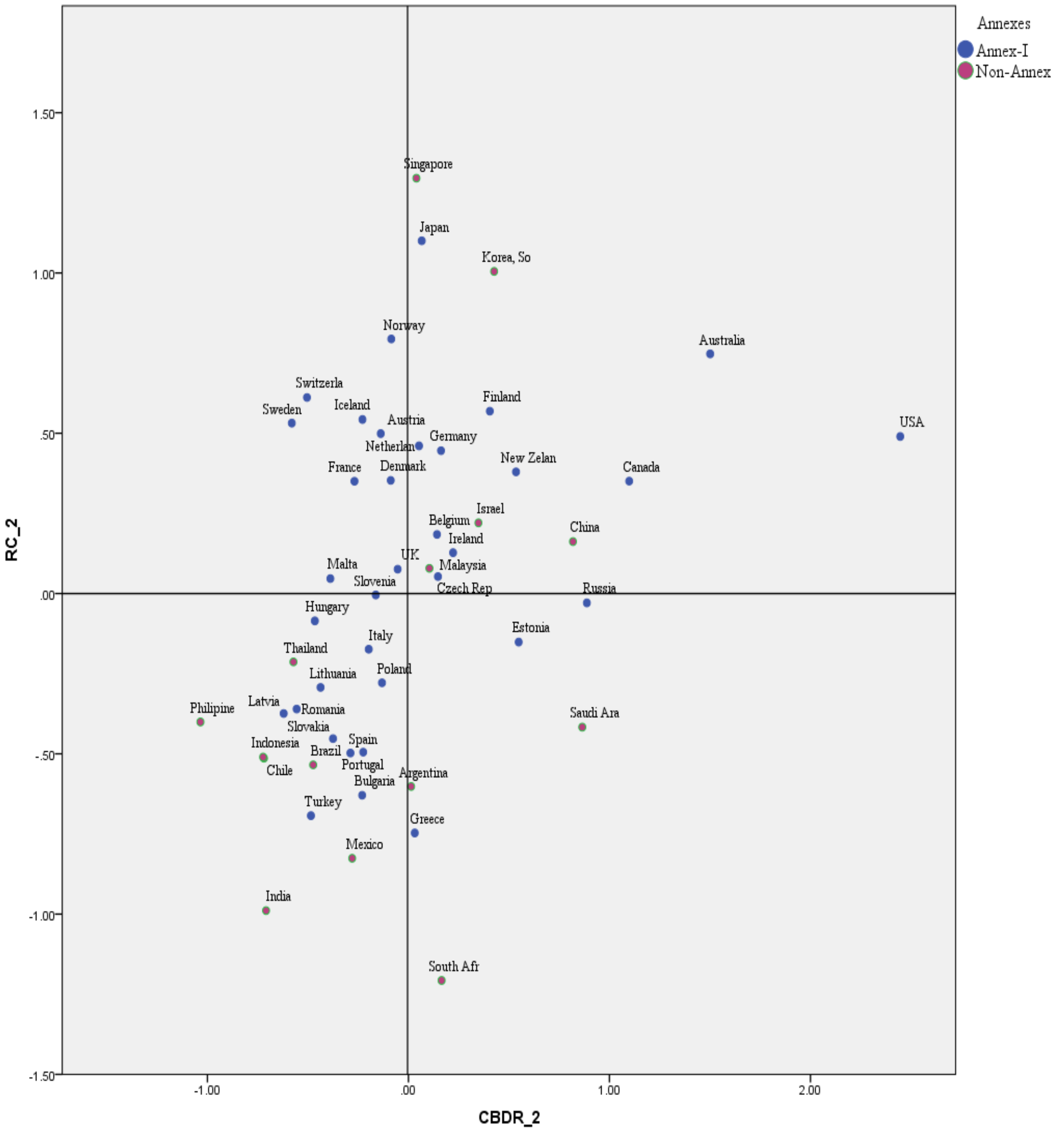

Figure 4-8: CBDR Index vs. RC Index for Method 2

CHAPTER 5

DISCUSSIONS AND RECOMMENDATIONS

Post-2020 climate change negotiations have been continuing under the UNFCCC, particularly in the ADP for a fair, equitable and comprehensive deal. The mandate of the ADP is to develop a legal instrument, a protocol, or an agreed outcome that is applicable to all countries (UNFCCC, 2012). This is a significant opportunity for the involvement of developing countries into the mitigation efforts (Aldy & Stavins, 2012). Because contribution from all countries with the widest comprehensive global cooperation in order to halt the increase of global average temperature is highly crucial to reach the ultimate objective of the UNFCCC (UNFCCC, 2012). 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 Article 3.1 of the UNFCCC. The aim of CBDR and RC principles in the UNFCCC is to ensure equity concerns in the allocation of responsibilities.

The global economy has changed since the early 1990s. Between 1992 and 2012, non-Annex I countries have gained a comparative advantage for being out of the quantified emission commitments. They hide behind their countries' low per capita income as of 1992 without making any contribution to global efforts (Harris, 2010). It is difficult to support the continuance of static classifications as Annex-I and non-Annex I, because the efforts from Annex-I countries only cannot be sufficient to reach the targets of the UNFCCC. Therefore, efforts from non-Annex I countries have been expected in accordance with the principles of CBDR and RC. Either to have further commitments or participations by other countries to mitigation efforts, differentiation via updated annex classifications and fair allocation of responsibilities in line with the twenty-first century's economic development conditions is required (Harris, 2013; Ott et al., 2004).

There is some factual evidence that current classifications do not reflect the fair allocation of responsibilities. For instance, China, as one of the top-2 emitters, does not have any legally binding emissions mitigation target. And the other champion, the

USA, has not taken serious actions similar to other Annex-II countries which are providing financial, technological and capacity building support to others. China's and the USA's total emissions together sum up to approximately 40% of total global emissions. Without the effective participation of these two large emitters in emission reduction efforts, it seems impossible to effectively address the global climate change problem. In addition to China, other non-Annex I countries such as Saudi Arabia, Indonesia, South Korea, India, Brazil, etc. also have high amount of emissions, but they also do not have any responsibilities to reduce their emissions. On the other hand, economic activities and related emissions of major developing countries in non-Annex I have been increasing. Moreover, they are converging towards Western style consumption with luxury emissions. Therefore, the exclusion of their emission mitigation responsibility is not in line with the climate justice (Harris, 2010). Lack of emission reduction targets for these countries poses a problem to global efforts. It should be possible for these countries to pitch in via changing consumption patterns.

This study attempts to introduce and develop a differentiation tool in order to update countries' position in the Annexes of the UNFCCC. This differentiation is based on the principles of CBDR and RC, which have their ground in the UNFCCC's related preambles and articles. In the study, economic, social, technical and climatic data are used and the statistical technique are employed for 50 countries. This is the first study that includes technical and social variables in the differentiation calculation by using PCA.

Two different methods are proposed for calculating the indices. Both methods use the PCA in order to calculate index scores and the CLA to group converging countries. The method 1 firstly calculate dimension indices and then aggregate the dimension for obtaining CBDR and RC scores. The method 2 does not use any dimension indices, it calculates overall CBDR and RC indices directly utilizing all indicators.

The method 1's CBDR index results suggest five main responsible groups that are ranked from the highest to the lowest. The USA and China fall into the first group being the most responsible countries to mitigate GHG emissions. Indonesia, Bulgaria, Iceland, Malta, Switzerland, Chile, Hungary, Slovakia, Sweden, Lithuania, Romania, Philippines and Latvia are the least responsible countries among 50 emitting countries.

CBDR index results by the method 2 presents that the USA falls into first groups alone and it is the most responsible country. Slovakia, Malta, Lithuania, Hungary, Brazil, Turkey, Switzerland, Romania, Thailand, Sweden, Latvia, India, Chile, Indonesia, Philippines are countries with lowest responsibilities among 50 emitting countries. In terms of generally ranking of 50 countries, both methods provide close results. The correlation between these two methods' country ranking for CBDR is 0.877. Thus, according to CBDR index scores for both methods, the USA is the most responsible country for emission reduction (Table 5-1). Both methods also refer that Slovakia, Malta, Lithuania, Hungary, Switzerland, Romania, Sweden, Latvia, Chile, Indonesia, and Philippines are the least responsible countries.

Table 5-1: Comparison of both methods for country groups (CBDR Index)

	Method 1	Method 2
Group-A	**USA**, China	**USA**
Group-B	**Australia, Russia, Saudi Arabia, Canada**	China, **Australia, Canada, Russia, Saudi Arabia**,
Group-C	**South Korea, Estonia, New Zealand, Japan, South Afr., Israel, Germany, Finland, Malaysia, Argentina**	**New Zealand**, **South Korea**, **Finland**, **Israel**, Ireland, **South Afr.**, **Germany**, Czech Rep, Belgium, **Malaysia**, **Japan**, **Estonia**, Netherlands, Singapore, Greece, **Argentina**
Group-D	Belgium, **Mexico**, Greece, Singapore, Netherlands, **UK**, Czech Rep, India, Ireland, **Italy**, **Portugal**, Thailand, Brazil, **Austria**, **Slovenia**, **France**, Turkey, **Spain**, **Poland**, **Norway**, **Denmark**	**UK, Norway, Denmark, Poland, Austria, Slovenia, Italy, Portugal,** Iceland, Bulgaria, **France, Mexico, Spain**
Group-E	**Indonesia**, Bulgaria, Iceland, **Malta**, **Switzerland**, **Chile**, **Hungary**, **Slovakia**, **Sweden**, **Lithuania**, **Romania**, **Philippines**, **Latvia**	**Slovakia**, **Malta**, **Lithuania**, **Hungary**, Brazil, Turkey, **Switzerland**, **Romania**, Thailand, **Sweden**, **Latvia**, India, **Chile**, **Indonesia**, **Philippines**

RC index according to the method 1 suggests that Japan, Norway, Singapore, Iceland, the USA, and South Korea are the most capable countries in combatting climate change. On the other hand, Argentina, India, Bulgaria, Turkey, Mexico, Greece and South Africa are the least capable for combatting climate change. RC index resulted by the method 2 suggests that Singapore, Japan, South Korea, Norway and Australia are the most capable countries, and Mexico, South Africa, Turkey, India, and Greece are least capable countries. The correlation between these two methods' country ranking for RC is 0.958. Thus, both methods for RC index give similar results. For RC index, both methods show that Singapore, Japan, South Korea, and Norway are the most capable countries for combatting climate change (Table 5-2). Also, both methods refer that Greece, Turkey, Mexico, India and South Africa are the least capable countries in terms of providing financial, technological and capacity building support to other countries.

Table 5-2: Comparison of both methods for country groups (RC Index)

	Method 1	Method 2
Group-A	**Japan**, **Norway**, **Singapore**, Iceland, USA, **South Korea**	**Singapore**, **Japan**, **South Korea**, **Norway**, Australia
Group-B	**Sweden**, Australia, **Switzerland**, **Finland**, **Austria**, **Germany**, China, **New Zealand**, **Denmark**, **Canada**, **Netherlands**	**Switzerland**, **Finland**, Iceland, **Sweden**, **Austria**, USA, **Netherlands**, **Germany**, **New Zealand**, **Denmark**, **Canada**, France
Group-C	France, **Belgium**, Israel, Slovenia, Russia, **Czech Rep**, **Ireland**, **UK**, Estonia, Italy	Israel, **Belgium**, China, **Ireland**, Malaysia, **UK**, **Czech Rep**, Malta, Slovenia, Russia, Hungary
Group-D	**Saudi Arabia**, Hungary, **Latvia**, Malaysia, **Indonesia**, **Thailand**, **Brazil**, **Romania**, Malta, **Poland**, **Spain**, **Lithuania**, **Portugal**, **Slovakia**, **Philippines**, **Chile**	Estonia, Italy, **Thailand**, **Poland**, **Lithuania**, **Romania**, **Latvia**, **Philippines**, **Saudi Arabia**, **Slovakia**, **Portugal**, **Spain**, **Indonesia**, **Chile**, **Brazil**, Argentina, Bulgaria
Group-E	Argentina, **India**, Bulgaria, **Turkey**, **Mexico**, **Greece**, **South Africa**	**Turkey**, Greece, **Mexico**, **India**, **South Africa**

Overall, when the rankings and grouping of both methods compared, there is no divergence between both methods. As shown in the Figure 5-1, both methods have similar results. The reason behind why the dimension indices are needed to calculate as in the method 1 is to determine different aspects of responsibility and capability for each country. When subject wise burden sharing or assistance are concerned, dimension indices can provide detail information about countries' national circumstances. Since every countries' assistance to vulnerable countries might not be in a similar manner, each countries' respective capabilities should be different regarding economic, social and technical perspectives. For instance, while one country with high technical capabilities can provide technology transfer to other incapable countries, this country might not be economically capable as well. But this country might be also capable to share its social development experience such as poverty eradication, and assist other countries in terms of its gained social capital.

The method 2 can be preferred to compare countries overall CBDR and RC conditions and national circumstances. For instance, one country can compare its commitment level with other countries through looking into the CBDR and RC indices. Besides, both indices scores can be used as a criterion whether committed efforts by countries reflects their actual ability or not. Besides, the method 2 can be preferred in case of adding or extracting variables in the analysis of indices. In the scope of this study, there are some limitations to cover all countries with much more data. When more data or indicator is available to include the calculation of indices, these data can be easily inserted to PCA.

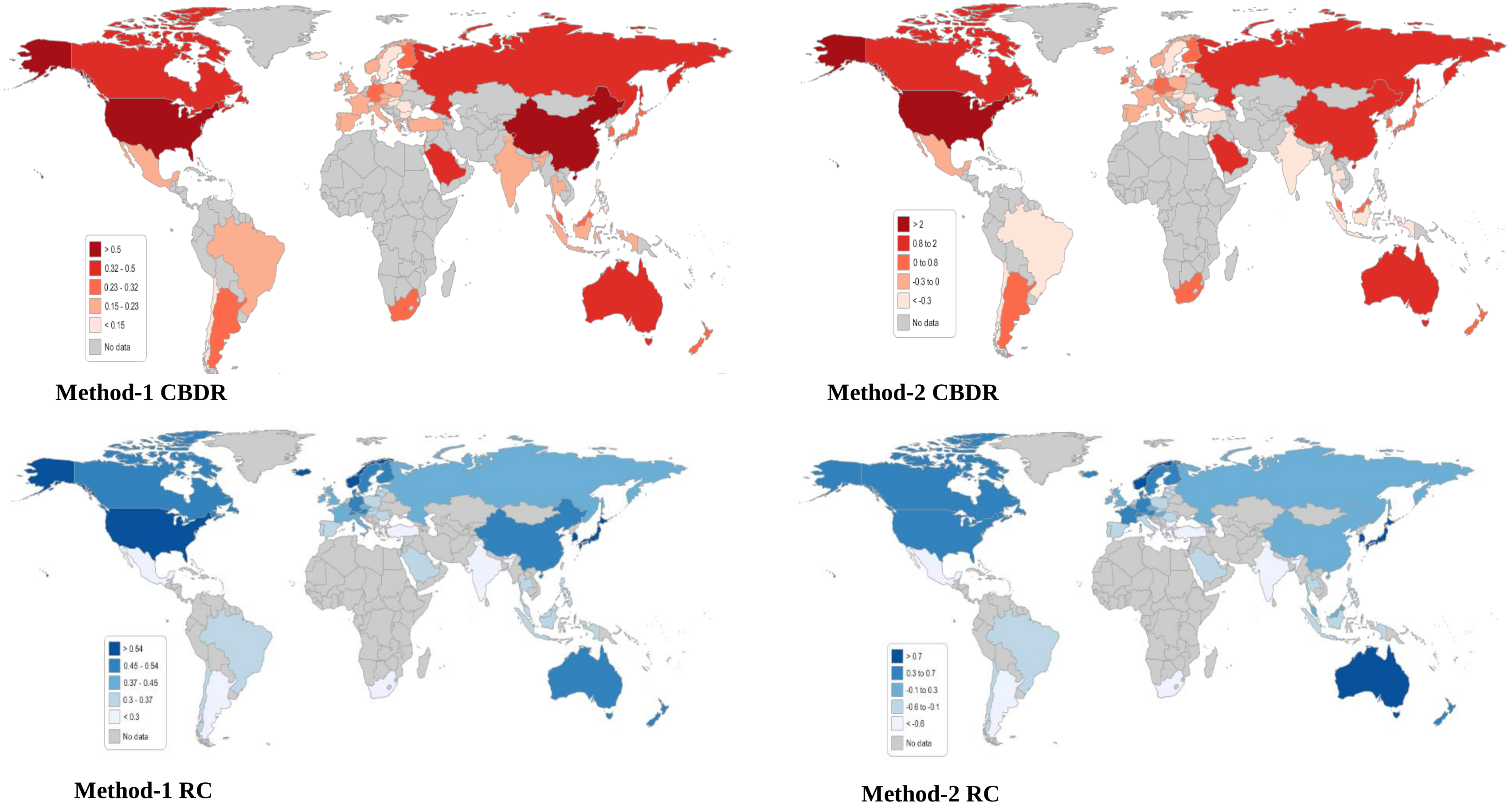

Figure 5-1: Comparison of Method 1 and Method 2 Results

While some countries have high CBDR index scores, they can have low RC Index scores. For example, Saudi Arabia and Russia have high CBDR Index, but their RC Index is low. These countries should be supported to reduce their emissions. Bulgaria, Chile, Turkey and Indonesia have low scores for both CBDR and RC Indices. They are not only less responsible, but also have low capabilities for reducing emissions. Additionally, many non-Annex I countries are more responsible than some Annex-I countries. So, the results suggest that it may not be fair enough to expect emission reduction from only Annex-I countries. And similarly, there is a potential to be triggered to extend Annex-II countries in order to accumulate more support. Although many non-Annex I countries such as Singapore, South Korea, China and Malaysia have not been providing financial and technical assistance to other developing countries for emission reduction, the results of this study suggest that these countries are highly capable to do the assistance.

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 with concerning 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.

5.1 Policy Recommendations

In the effort to mitigate post-2020 emissions, allocate responsibilities fairly, and expand the number of responsible countries, there are three main possibilities. Because climate negotiations are now going on under the ADP, and are particularly focused on the new structure of burden-sharing in the post-2020 climate regime, 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.

1. The first recommendation is based on the ranking of countries according to the results of CBDR and RC indices. With this recommendation, Annexes,

developed-developing or north-south distinctions do not matter. 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.

2. The second recommendation is based on expanding the list of Annex-I countries. As revealed, some non-Annex I countries are more responsible for mitigating their emissions than many of Annex-I countries. According to the common finding of two methods, some of the non-Annex I countries such as Saudi Arabia, China, South Korea, South Africa, Israel, Malaysia and Argentina can be graduated to Annex-I. These countries should adopt commitments similar to current Annex-I countries. Such countries can be encouraged to adopt emission mitigation targets, while being given some flexibility, such as a different base year from which to reduce emissions, or sector-specific emission reductions. Additionally, some non-Annex I countries with high RC scores should provide financial and technical assistance to other vulnerable countries and least-developed countries. Then, the list of Annex-I countries can be regularly updated prior to the beginning of every new commitment period. The amount of quantified emissions reduction targets and the base year of this commitment among new Annex-I countries requires further analyses.
3. The third alternative is based on all countries' efforts according to self-differentiation. According to the mandate of ADP, 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.

The further applications of these indices should be used in the different perspectives of climate change. Inter-linkages between CBDR-RC indices and adaptation to climate change, mobilization of financial resources, compensation for the most vulnerable country's loss and damage should be investigated in the future studies. These indices can be also used to determine countries' absolute emission reduction targets for stabilization of GHG emission concentration in the atmosphere. Similar studies with creating indices in order to analyze adaptation needs and development needs of vulnerable countries in the context of climate change can be conducted in the future.

CHAPTER 6

CONCLUSION

Comprehensive and inclusive participation of all countries is necessary to reduce GHG emissions. A country's contribution for emission reduction should be based on its national circumstances according to CBDR and RC principles as well as equity. The principles, preambles and articles of the UNFCCC present a well-prepared agreement and guide to international collaboration for combatting climate change, but the existence of annexes without considering countries’ national circumstances creates a status quo. The current classifications as Annex-I and non-Annex I, or developed and developing countries, fail to achieve essential emission mitigation. In fact, there is no distinction between Annex-I and non-Annex I countries in terms of their economic, social, technical and environmental perspectives. The current distinction in the annexes is not in line with countries' national circumstances, particularly in terms of responsibility and capability; therefore, it may not be considered as fair to use institutional criteria, such as being a member of the OECD (as applied in the early 90s in the UNFCCC), to allocate limitation responsibility.

In this study, it is argued that updating annexes of the UNFCCC with dynamic, rational, applicable and quantifiable methods for fair burden-sharing is urgent. A more transparent and inclusive structure based on scientific knowledge and common understanding for the allocation of responsibilities is needed. In this study an attempt for operationalization of the main principles of the UNFCCC through creating CBDR and RC indices can assist to achieve equity-based emission mitigation. This attempt brings a new approach with an innovative classification method which quantitatively explains countries’ national circumstances with regards to CBDR and RC principles. The results of this attempt argue that the current classifications of UNFCCC countries is not legitimate in terms of equity, fairness and justice according to the rankings of countries’ CBDR and RC indices. For instance, many non-Annex I countries are more responsible and capable with regard to their emission reduction than a significant number of Annex-I countries. Divergence between Annex-I and non-Annex I countries is actually not observed; on the contrary, there is some convergence among these groups. The current discussions for the post-2020 international climate change agreement are a great opportunity to change the status quo originating from the existence of annexes. With the establishment of the ADP in 2011, no divergence or distinction of country groups has been made. The recent discussions and progresses of 2014 are parallel the ADP's mandate of the need for change in the current classification. It is emphasized that all countries' participation, inclusion and contribution through their national circumstances are needed to reach the ultimate objective of the UNFCCC.

In conclusion, introducing and developing a new approach for a fair classification of countries according to the principles of the UNFCCC can assist policymakers and negotiators in the post-2020 climate negotiations. The approach in this study can offer a crucial opportunity to establish a lasting framework for the fair allocation of responsibilities.

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APPENDIX

Table A- 1: Sectoral per Capita GHG Emissions[10] (per capita ton CO_2 eqv.)

Country	Energy	Industry	Agriculture	Waste	Aggregate
Argentina	4.561	0.209	3.593	0.384	0.331
Australia	**19.322**	0.738	4.441	0.644	**0.681**
Austria	7.750	0.522	0.904	0.232	0.327
Belgium	9.513	0.820	0.906	0.090	0.379
Brazil	1.908	0.218	3.124	0.222	0.258
Bulgaria	5.901	0.389	0.833	0.632	0.349
Canada	17.743	0.617	1.933	0.650	0.571
Chile	4.102	0.183	0.823	0.162	0.204
China	5.425	0.728	0.525	0.146	0.311
Czech Republic	11.147	0.358	0.809	0.297	0.347
Denmark	8.670	0.380	1.421	0.236	0.327
Estonia	11.649	0.143	0.899	0.540	0.359
Finland	10.563	0.965	1.134	0.414	0.483
France	5.558	0.378	1.591	0.308	0.306
Germany	9.397	0.505	0.775	0.144	0.325
Greece	8.238	0.875	0.884	0.298	0.410
Hungary	5.062	0.368	0.872	0.370	0.289
Iceland	2.165	0.484	1.800	0.655	0.352
India	1.449	0.123	0.293	0.047	**0.125**
Indonesia	1.945	**0.091**	1.031	0.260	0.183
Ireland	8.896	0.690	4.130	0.314	0.476
Israel	8.605	**1.286**	0.190	0.836	0.569
Italy	6.668	0.519	0.648	0.280	0.315
Japan	8.658	0.614	0.211	**0.038**	0.301
Korea, (South)	10.699	1.211	0.319	0.224	0.474
Latvia	3.425	0.301	0.998	0.381	0.262
Lithuania	3.887	0.656	1.361	0.426	0.352
Malaysia	6.992	0.474	0.887	**1.293**	0.498
Malta	5.942	0.499	0.211	0.520	0.333
Mexico	3.990	0.316	0.518	0.894	0.350
Netherlands	10.821	0.376	1.075	0.320	0.358
New Zealand	7.615	0.398	**8.044**	0.459	0.540
Norway	8.135	0.835	0.913	0.239	0.392
Philippines	**0.833**	0.115	0.472	0.107	0.131
Poland	7.980	0.332	0.901	0.229	0.294
Portugal	5.112	0.667	0.916	0.711	0.408
Romania	4.308	0.369	1.257	0.230	0.265
Russian Federation	13.694	0.422	1.111	0.503	0.436
Saudi Arabia	15.681	0.893	0.487	0.881	0.599
Singapore	11.366	0.600	**0.037**	0.278	0.370
Slovakia	6.395	0.413	0.462	0.450	0.317
Slovenia	7.732	0.481	1.007	0.297	0.333
South Africa	7.786	0.351	0.686	0.390	0.318
Spain	6.283	0.470	0.907	0.343	0.319
Sweden	4.644	0.350	0.880	0.195	0.249
Switzerland	5.550	0.402	0.733	0.075	0.244
Thailand	3.682	0.297	0.914	0.149	0.220
Turkey	3.703	0.413	0.576	0.470	0.290
United Kingdom	7.774	0.253	0.789	0.337	0.292
United States	18.115	0.737	1.490	0.520	0.562

[10](WRI, 2014)

Table A- 2: Consumption Based per Capita Emissions, Historical emissions, Share of Global Emissions

Country	Consumption CO_2/cap[11]	Historical Emissions[12]	Share of Emissions[13]
Argentina	3.82	6577	0.81%
Australia	17.33	14335	1.32%
Austria	11.25	4765	0.19%
Belgium	13.93	11315	0.35%
Brazil	2.04	10938	2.61%
Bulgaria	4.47	3340	0.14%
Canada	15.65	27170	1.63%
Chile	3.66	2105	0.23%
China	3.53	132558	23.32%
Czech Republic	11.02	2333	0.26%
Denmark	12.77	3612	0.13%
Estonia	10.28	325	0.05%
Finland	12.81	2647	0.16%
France	8.36	34615	1.22%
Germany	11.94	83533	2.08%
Greece	11.35	3085	0.26%
Hungary	6.53	4485	0.16%
Iceland	9.60	101	0.01%
India	1.09	37620	5.22%
Indonesia	1.44	8808	1.85%
Ireland	12.28	1789	0.14%
Israel	10.03	1816	0.20%
Italy	9.69	20703	1.16%
Japan	11.31	48575	2.92%
Korea, (South)	10.16	11673	1.52%
Latvia	4.25	159	0.03%
Lithuania	4.92	283	0.05%
Malaysia	4.67	3467	0.65%
Malta	7.58	**80**	0.02%
Mexico	4.07	15168	1.55%
Netherlands	10.49	10074	0.64%
New Zealand	8.69	1497	0.17%
Norway	12.13	2146	0.13%
Philippines	1.01	2241	0.33%
Poland	7.85	24344	0.85%
Portugal	7.42	2070	0.18%
Romania	4.21	7670	0.29%
Russian Federation	7.23	144506	5.22%
Saudi Arabia	11.96	9705	1.22%
Singapore	12.55	1512	0.53%
Slovakia	7.32	748	0.10%
Slovenia	9.32	287	0.04%
South Africa	7.62	16428	1.26%
Spain	8.85	11935	0.92%
Sweden	8.36	4466	0.17%
Switzerland	10.17	2563	0.12%
Thailand	2.97	5074	0.86%
Turkey	4.29	6692	0.87%
United Kingdom	11.47	73542	1.41%
United States	21.40	**355503**	15.42%

[11] The Carbon Dioxide Embodied in International Trade dataset is derived from OECD Input Output Tables linked together using Bilateral Trade Database in goods by industry and end-use category BTDIxE and energy statistics (OECD, 2014)

[12] Millions tons of CO_2 emissions from fossil fuel combustion and cement production (CDIAC, 2014)

[13] (WRI, 2014)

Table A- 3: Indicators for Economic Capability Dimension

Country	**GDP[14]**	**GDP/cap[15]**	**Gross sav. (%GDP)[16]**
Argentina	291.42	14,376	22.31
Australia	846.20	34,621	24.53
Austria	337.69	35,313	24.66
Belgium	406.85	32,877	21.96
Brazil	1,136.56	10,079	17.23
Bulgaria	33.85	11,505	21.77
Canada	1,255.42	35,223	20.78
Chile	164.99	14,435	22.28
China	4,522.14	6,819	50.12
Czech Republic	149.62	23,625	21.57
Denmark	259.16	32,379	23.48
Estonia	15.83	16,740	26.75
Finland	207.99	31,310	19.25
France	2,249.45	29,522	18.16
Germany	3,073.86	33,565	24.42
Greece	209.56	23,999	**5.37**
Hungary	109.13	16,972	23.30
Iceland	17.06	32,754	8.04
India	1,368.76	**3,122**	31.36
Indonesia	427.48	3,873	32.05
Ireland	211.71	36,818	13.23
Israel	178.77	26,197	14.80
Italy	1,727.41	27,059	16.78
Japan	4,711.87	31,030	21.93
Korea (South)	1,078.21	26,774	31.56
Latvia	17.14	12,785	25.69
Lithuania	30.06	15,559	17.09
Malaysia	198.43	13,767	34.85
Malta	6.84	22,697	11.63
Mexico	1,032.69	11,979	21.61
Netherlands	680.92	36,925	25.23
New Zealand	123.91	25,051	14.63
Norway	329.52	46,774	36.89
Philippines	145.16	3,554	25.12
Poland	407.55	17,372	17.69
Portugal	188.42	21,780	12.18
Romania	119.20	10,792	26.79
Russian Federation	980.91	14,182	30.55
Saudi Arabia	497.62	24,864	**50.46**
Singapore	180.56	**52,314**	46.60
Slovakia	80.63	20,159	21.97
Slovenia	38.32	25,023	21.40
South Africa	307.31	9,516	16.11
Spain	1,160.46	26,901	17.56
Sweden	417.35	34,125	26.58
Switzerland	439.80	39,072	30.57
Thailand	223.90	7,987	30.73
Turkey	628.43	12,671	14.09
United Kingdom	2,389.38	32,809	13.42
United States	14,231.60	42,001	15.94

[14] Constant, 2005 $ billion US
[15] (WDI, 2013)
[16] (WDI, 2013)

Table A- 4: Patent number, exporting high technology products, Renewable Energy Sources, R&D expenditure

Country	Patent number[17]	High tech[18] (%)	Renew[19] (%)	R&D[20]
Argentina	30.60	7.50	7.20	0.62
Australia	653.70	11.88	5.10	2.38
Austria	134.60	11.91	26.60	2.79
Belgium	49.70	10.47	4.80	2.00
Brazil	16.70	11.21	42.90	1.16
Bulgaria	33.50	7.91	7.00	0.60
Canada	562.10	14.05	18.00	1.85
Chile	59.60	5.48	23.10	0.42
China	100.70	27.51	10.70	1.76
Czech Republic	86.80	15.30	6.90	1.55
Denmark	27.90	14.11	22.20	3.07
Estonia	89.50	9.27	14.80	1.63
Finland	172.10	10.94	26.10	3.90
France	157.70	24.92	7.20	2.24
Germany	166.20	15.25	10.00	2.80
Greece	42.20	10.15	8.00	0.60
Hungary	6.50	24.01	7.60	1.16
Iceland	434.20	20.86	**83.80**	2.65
India	5.10	7.18	26.50	0.76
Indonesia	230.00	9.78	33.60	**0.08**
Ireland	54.40	21.23	6.20	1.71
Israel	502.00	14.66	4.90	**4.35**
Italy	303.40	7.24	11.90	1.26
Japan	**1759.90**	17.96	4.20	3.26
Korea, (South)	1428.80	29.47	0.70	3.74
Latvia	81.70	7.64	32.80	0.60
Lithuania	25.30	10.61	14.50	0.80
Malaysia	76.70	44.52	5.50	1.07
Malta	9.60	47.08	5.40	0.68
Mexico	82.90	16.94	9.30	0.48
Netherlands	117.60	21.29	4.30	1.85
New Zealand	995.20	9.00	40.40	1.30
Norway	334.00	16.15	42.80	1.69
Philippines	**3.80**	**55.43**	40.30	0.11
Poland	78.50	6.69	7.80	0.74
Portugal	13.10	3.41	22.30	1.59
Romania	20.80	10.95	14.10	0.46
Russian	212.10	9.28	2.40	1.16
Saudi Arabia	7.10	**0.73**	0.00	0.08
Singapore	873.30	49.91	2.20	2.09
Slovakia	68.80	6.77	7.40	0.63
Slovenia	123.20	5.72	13.10	2.11
South Africa	106.30	4.28	10.50	0.87
Spain	60.20	6.36	11.70	1.39
Sweden	147.10	13.70	32.10	3.39
Switzerland	96.70	24.84	18.10	2.87
Thailand	11.20	24.02	18.90	0.25
Turkey	9.00	1.93	10.00	0.84
United Kingdom	90.20	21.02	4.10	1.80
United States	707.60	8.10	6.10	2.80

[17] Patents granted to residents and non-residents in 2010, per million people (UNDP, 2013b)
[18] High technology exports: High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery (% of manufactured exports) (WDI, 2013)
[19] The share of renewable sources in the total primary energy sources in 2011 (IEA, 2013b)
[20] Research and development expenditure, % of GDP in 2010 (UNDP, 2013b)

Table A- 5: Literacy Rate, Number of Hospital Bed, Unemployment Rate

Country	Literacy Rate[21]	Hospital Bed.#[22]	Unempl.[23]
Argentina	97.86	45	7.20
Australia	99.00	39	5.20
Austria	98.00	76	4.30
Belgium	99.00	65	7.50
Brazil	90.40	23	6.70
Bulgaria	98.35	65	12.30
Canada	99.00	32	7.20
Chile	98.60	20	6.40
China	95.10	39	4.00
Czech Republic	99.00	70	7.00
Denmark	99.00	35	7.50
Estonia	99.80	53	10.10
Finland	100.00	58	7.60
France	99.00	66	9.90
Germany	99.00	82	5.40
Greece	97.30	48	24.20
Hungary	99.05	72	10.90
Iceland	99.00	58	6.00
India	62.80	9	3.60
Indonesia	92.81	6	6.60
Ireland	99.00	31	14.70
Israel	97.10	34	6.90
Italy	98.98	35	10.70
Japan	99.00	**137**	4.30
Korea, Rep. (South)	97.10	103	3.20
Latvia	99.78	53	14.90
Lithuania	99.70	68	13.20
Malaysia	93.10	18	3.00
Malta	92.40	44	6.40
Mexico	93.52	17	4.90
Netherlands	99.00	47	5.30
New Zealand	99.00	23	6.90
Norway	100.00	33	3.20
Philippines	95.40	**5**	7.00
Poland	99.73	66	10.10
Portugal	95.43	33	15.60
Romania	97.70	63	7.00
Russian Federation	99.70	97	5.50
Saudi Arabia	87.16	22	5.60
Singapore	95.90	27	2.80
Slovakia	99.60	64	13.90
Slovenia	99.69	46	8.80
South Africa	92.98	28	25.00
Spain	97.70	32	**25.00**
Sweden	99.00	27	8.00
Switzerland	99.00	50	4.20
Thailand	93.50	21	**0.70**
Turkey	94.11	25	9.20
United Kingdom	99.00	30	7.90
United States	99.00	30	0.51

[21] (CIA, 2014)
[22] (WHO, 2013)
[23] (WDI, 2013)

Table A- 6: Income Inequality, Secondary School Enrolment and Poverty Rate

	Income Inequality	Sec. School En.	Poverty
Argentina	55.51	89	0.42
Australia	69.7	129	1
Austria	73.7	100	0.88
Belgium	72	111	0.7
Brazil	48.1	101	0.58
Bulgaria	54.7	88	0.58
Canada	67.9	101	0.82
Chile	47.94	88	0.71
China	52.6	81	0.74
Czech Rep	69	90	0.83
Denmark	75.2	117	0.74
Estonia	68.7	104	0.66
Finland	73.2	108	1
France	67.3	113	0.85
Germany	73	103	0.7
Greece	67	101	0.61
Hungary	75.3	98	0.73
Iceland	72	107	1
India	66.1	60	0.42
Indonesia	64.43	77	0.77
Ireland	66.1	117	0.89
Israel	60.8	91	0.54
Italy	68.1	99	0.62
Japan	72.4	102	0.69
Korea, So	58.1	97	0.68
Latvia	64.8	95	0.89
Lithuania	62.43	98	0.92
Malaysia	53.79	68	0.93
Malta	72.6	105	0.7
Mexico	52.84	87	0
Netherland	69.1	120	0.8
New Zeeland	63.8	119	1
Norway	75	110	1
Philippines	57.02	85	0.48
Poland	66.25	97	0.8
Portugal	61.5	107	0.65
Romania	75.76	95	0.57
Russia	58.3	89	0.75
Saudi Arabia	68	101	0.36
Singapore	52.2	106.9	1
Slovakia	74	89	0.59
Slovenia	76.2	97	0.74
South Afr.	36.86	94	0.39
Spain	68	119	0.59
Sweden	77	100	1
Switzerland	70.4	95	0.85
Thailand	60.63	79	0.85
Turkey	59.97	78	0.67
UK	60	102	0.73
USA	55	96	0.71

Table A- 7: Correlation Matrix of CBDR Emission Level Dimension

	GHG	Cum.GHG. Since.1990	Cum.CO_2.Since.1850
GHG	1.000		
Cum.GHG.Since.1990	0.963	1.000	
Cum.CO_2.Since.1850	0.783	0.916	1.000

Table A- 8: KMO and Bartlett's Test of CBDR Emission Level Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.468
Bartlett's Test of Sphericity	Approx. Chi-Square	289.037
	df	3
	Sig.	.000

Table A- 9: Correlation Matrix of CBDR Emission Level Dimension

	GHG	Cum.CO_2.Since.1850
GHG	1.000	
Cum.CO_2.Since.1850	0.783	1.000

Table A- 10: KMO and Bartlett's Test of CBDR Emission Level Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.500
Bartlett's Test of Sphericity	Approx. Chi-Square	45.105
	df	1
	Sig.	.000

Table A- 11: KMO and Bartlett's Test of CBDR Emission Intensity Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.507
Bartlett's Test of Sphericity	Approx. Chi-Square	175.563
	df	15
	Sig.	.000

Table A- 12: KMO and Bartlett's Test of CBDR Index (Method 1)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.500
Bartlett's Test of Sphericity	Approx. Chi-Square	4.281
	Df	1
	Sig.	0.039

Table A- 13: KMO and Bartlett's Test of RC Economic Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.504
Bartlett's Test of Sphericity	Approx. Chi-Square	2.036
	Df	3
	Sig.	0.565

Table A- 14: KMO and Bartlett's Test of RC Technical Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.512
Bartlett's Test of Sphericity	Approx. Chi-Square	14.748
	Df	6
	Sig.	0.022

Table A- 15: KMO and Bartlett's Test of RC Social Dimension

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.592
Bartlett's Test of Sphericity	Approx. Chi-Square	57.584
	Df	15
	Sig.	.000

Table A- 16: KMO and Bartlett's Test of Overall RC Index (Method 1)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.634
Bartlett's Test of Sphericity	Approx. Chi-Square	24.395
	Df	3
	Sig.	.000

Table A- 17: KMO and Bartlett's Test of CBDR Index (Method 2)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.478
Bartlett's Test of Sphericity	Approx. Chi-Square	530.859
	df	36
	Sig.	.000

Table A- 18: Correlation Matrix (Method 2)

	GHG	GHG/cpt	Δ(GHG/cpt)	GHG/GDP	Δ(GHG/GDP)	Cum.GHG.1990	Cum.CO_2.1850	Cons.CO_2/cpt	Sec.GHG/cpt
GHG	1.000								
GHG/cpt	0.115	1.000							
Δ(GHG/cpt)	0.461	-.145	1.000						
GHG/GDP	0.391	0.332	0.216	1.000					
Δ(GHG/GDP)	-0.154	0.125	0.357	0.045	1.000				
Cum.GHG.1990	0.963	0.213	0.326	0.349	-0.117	1.000			
Cum.CO_2.1850	0.783	0.328	0.064	0.202	-0.112	0.916	1.000		
Cons.CO_2/cpt	0.044	0.814	-0.296	-0.126	0.042	0.169	0.369	1.000	
Sec.GHG/cpt	0.059	0.871	-0.015	0.272	0.190	0.122	0.198	0.676	1.000

Table A- 19: Correlation Matrix (Method 2)

	GHG	GHG/GDP	Δ(GHG/GDP)	GHG/cpt	Cum.CO_2.1850	Cons.CO_2/cpt	Sec.GHG/cpt
GHG	1.000						
GHG/GDP	0.391	1.000					
Δ(GHG/GDP)	-0.154	0.045	1.000				
GHG/cpt	0.115	0.332	0.125	1.000			
Cum.CO_2.1850	0.783	0.202	-0.112	0.328	1.000		
Cons.CO_2/cpt	0.044	-0.126	0.042	0.814	0.369	1.000	
Sec.GHG/cpt	0.059	0.272	0.190	0.871	0.198	0.676	1.000

Table A- 20: KMO and Bartlett's Test of RC Index (Method 2)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.525
Bartlett's Test of Sphericity	Approx. Chi-Square	233.572
	df	21
	Sig.	.000

Table A- 21: Rotated Component Matrix[a] of CBDR Index (Method 2)

	Component		
	1	2	3
GHG.PER.CPT	.934		
CONS.PER.CO2	.929		
SEC.AGG.PER.CPT	.884		
GHG		.929	
CUM.CO2.SINCE.1850		.866	
GHG.PER.GDP		.396	.812
CHNG.PER.GHG.GDP		-.400	.572

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser normalization.[a]

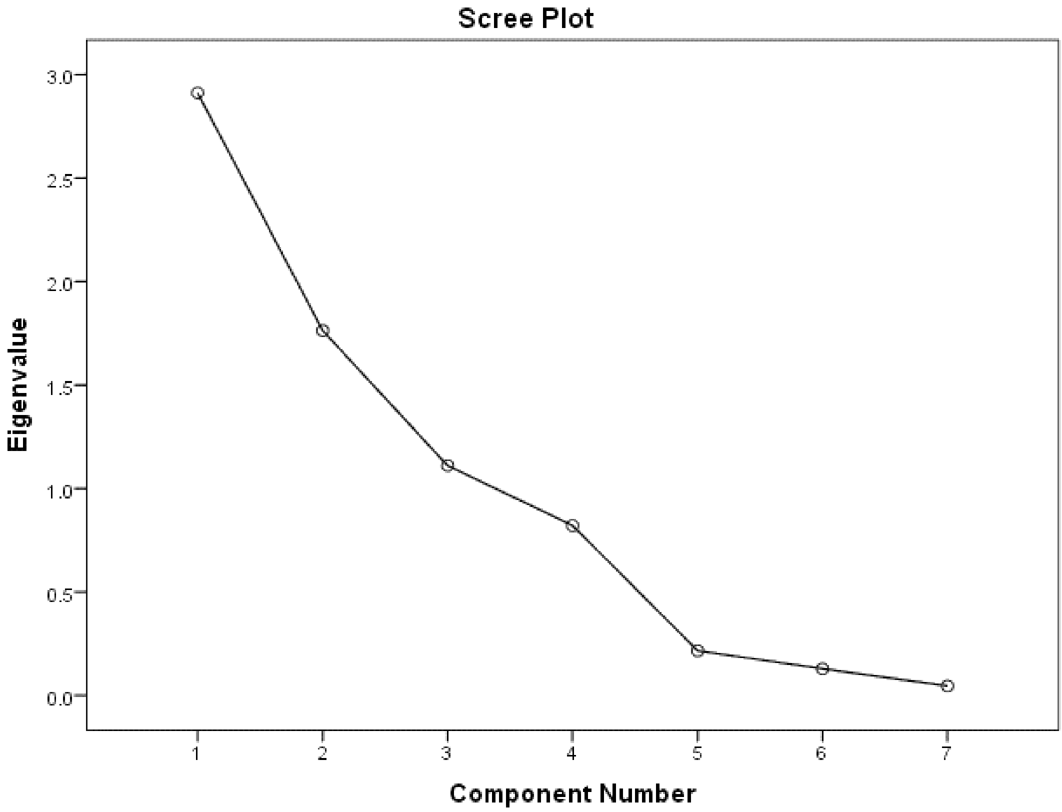

Figure A- 1: Scree Plot of CBDR Components (Method-2)

Table A- 22: KMO and Bartlett's Test of RC Index (Method 2)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.683
Bartlett's Test of Sphericity	Approx. Chi-Square	194.129
	Df	66
	Sig.	.000

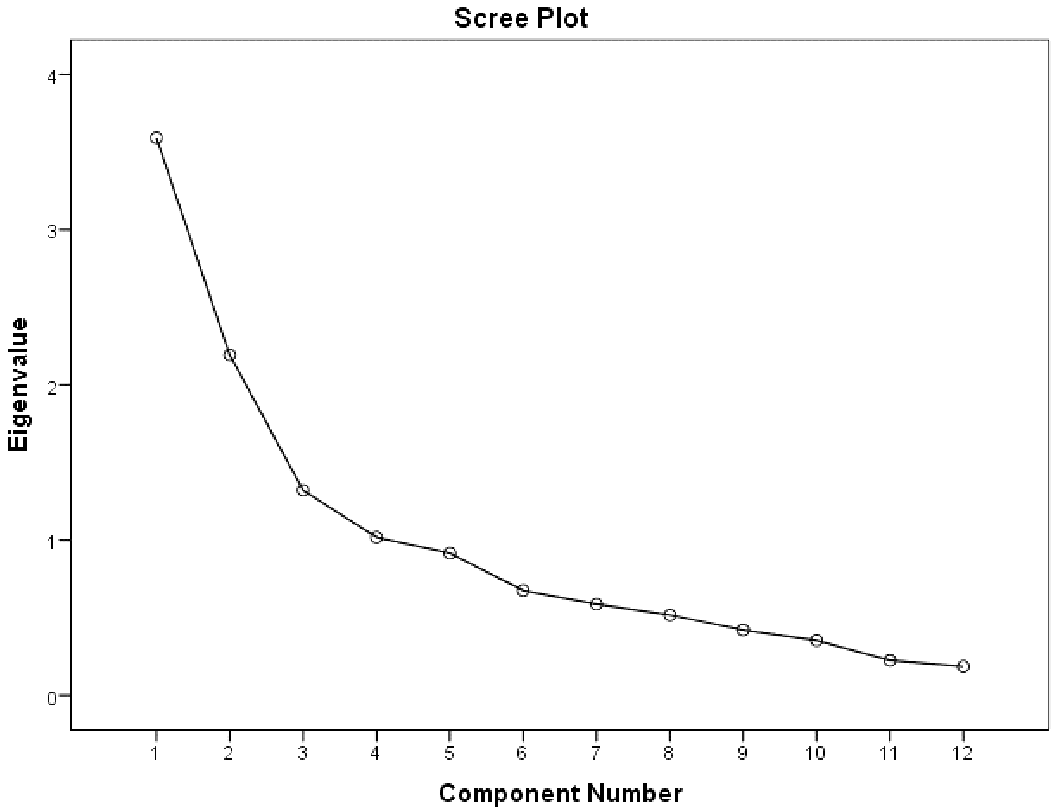

Figure A- 2: Scree Plot of RC Components (Method-2)

Table A- 23: The Comparison of CBDR Index for Both Methods

Rank	Country	Method 1	Rank	Country	Method 2
1	USA	0.736	1	USA	2.447
2	China	0.564	2	Australia	1.501
3	Australia	0.386	3	Canada	1.098
4	Russia	0.380	4	Russia	0.887
5	Saudi Arabia	0.354	5	Saudi Arabia	0.865
6	Canada	0.352	6	China	0.818
7	South Korea	0.308	7	Estonia	0.548
8	Estonia	0.282	8	New Zealand	0.535
9	New Zealand	0.259	9	South Korea	0.426
10	Japan	0.256	10	Finland	0.405
11	South Afr.	0.255	11	Israel	0.348
12	Israel	0.251	12	Ireland	0.222
13	Germany	0.242	13	South Afr.	0.165
14	Finland	0.242	14	Germany	0.162
15	Malaysia	0.238	15	Czech Rep	0.147
16	Argentina	0.233	16	Belgium	0.142
17	Belgium	0.211	17	Malaysia	0.104
18	Mexico	0.210	18	Japan	0.066
19	Greece	0.201	19	Netherlands	0.052
20	Singapore	0.200	20	Singapore	0.039
21	Netherland	0.199	21	Greece	0.031
22	UK	0.199	22	Argentina	0.013
23	Czech Rep	0.196	23	UK	-0.054
24	India	0.195	24	Norway	-0.085
25	Ireland	0.192	25	Denmark	-0.088
26	Italy	0.191	26	Poland	-0.132
27	Portugal	0.185	27	Austria	-0.138
28	Thailand	0.184	28	Slovenia	-0.163
29	Brazil	0.183	29	Italy	-0.197
30	Austria	0.183	30	Portugal	-0.225
31	Slovenia	0.178	31	Iceland	-0.229
32	France	0.177	32	Bulgaria	-0.230
33	Turkey	0.177	33	France	-0.269
34	Spain	0.176	34	Mexico	-0.280
35	Poland	0.174	35	Spain	-0.289
36	Norway	0.174	36	Slovakia	-0.375
37	Denmark	0.172	37	Malta	-0.389
38	Indonesia	0.151	38	Lithuania	-0.437
39	Bulgaria	0.146	39	Hungary	-0.466
40	Iceland	0.145	40	Brazil	-0.474
41	Malta	0.140	41	Turkey	-0.485
42	Switzerland	0.132	42	Switzerland	-0.505
43	Chile	0.132	43	Romania	-0.556
44	Hungary	0.124	44	Thailand	-0.572
45	Slovakia	0.113	45	Sweden	-0.580
46	Sweden	0.108	46	Latvia	-0.621
47	Lithuania	0.104	47	India	-0.708
48	Romania	0.099	48	Chile	-0.719
49	Philippines	0.095	49	Indonesia	-0.723
50	Latvia	0.089	50	Philippines	-1.035

Table A- 24: The comparison of RC index for both methods

Rank	Country	RC Index	Rank	Country	RC Index
1	Japan	0.589	1	Singapore	1.296
2	Norway	0.583	2	Japan	1.100
3	Singapore	0.575	3	South Korea	1.005
4	Iceland	0.555	4	Norway	0.794
5	USA	0.547	5	Australia	0.748
6	South Korea	0.544	6	Switzerland	0.612
7	Sweden	0.515	7	Finland	0.569
8	Australia	0.509	8	Iceland	0.543
9	Switzerland	0.504	9	Sweden	0.532
10	Finland	0.504	10	Austria	0.499
11	Austria	0.502	11	USA	0.490
12	Germany	0.487	12	Netherlands	0.461
13	China	0.482	13	Germany	0.446
14	New Zealand	0.478	14	New Zealand	0.380
15	Denmark	0.475	15	Denmark	0.353
16	Canada	0.462	16	Canada	0.351
17	Netherlands	0.457	17	France	0.350
18	France	0.435	18	Israel	0.220
19	Belgium	0.422	19	Belgium	0.184
20	Israel	0.417	20	China	0.162
21	Slovenia	0.403	21	Ireland	0.127
22	Russia	0.39	22	Malaysia	0.079
23	Czech Rep	0.384	23	UK	0.076
24	Ireland	0.384	24	Czech Rep	0.053
25	UK	0.383	25	Malta	0.047
26	Estonia	0.38	26	Slovenia	-0.004
27	Italy	0.379	27	Russia	-0.029
28	Saudi Arabia	0.368	28	Hungary	-0.085
29	Hungary	0.36	29	Estonia	-0.151
30	Latvia	0.357	30	Italy	-0.174
31	Malaysia	0.353	31	Thailand	-0.213
32	Indonesia	0.346	32	Poland	-0.278
33	Thailand	0.345	33	Lithuania	-0.293
34	Brazil	0.345	34	Romania	-0.360
35	Romania	0.345	35	Latvia	-0.374
36	Malta	0.339	36	Philippines	-0.401
37	Poland	0.336	37	Saudi Arabia	-0.417
38	Spain	0.333	38	Slovakia	-0.453
39	Lithuania	0.328	39	Portugal	-0.495
40	Portugal	0.325	40	Spain	-0.498
41	Slovakia	0.323	41	Indonesia	-0.510
42	Philippines	0.319	42	Chile	-0.514
43	Chile	0.315	43	Brazil	-0.534
44	Argentina	0.291	44	Argentina	-0.602
45	India	0.288	45	Bulgaria	-0.629
46	Bulgaria	0.278	46	Turkey	-0.693
47	Turkey	0.271	47	Greece	-0.747
48	Mexico	0.27	48	Mexico	-0.826
49	Greece	0.252	49	India	-0.989
50	South Afr.	0.192	50	South Afr.	-1.207

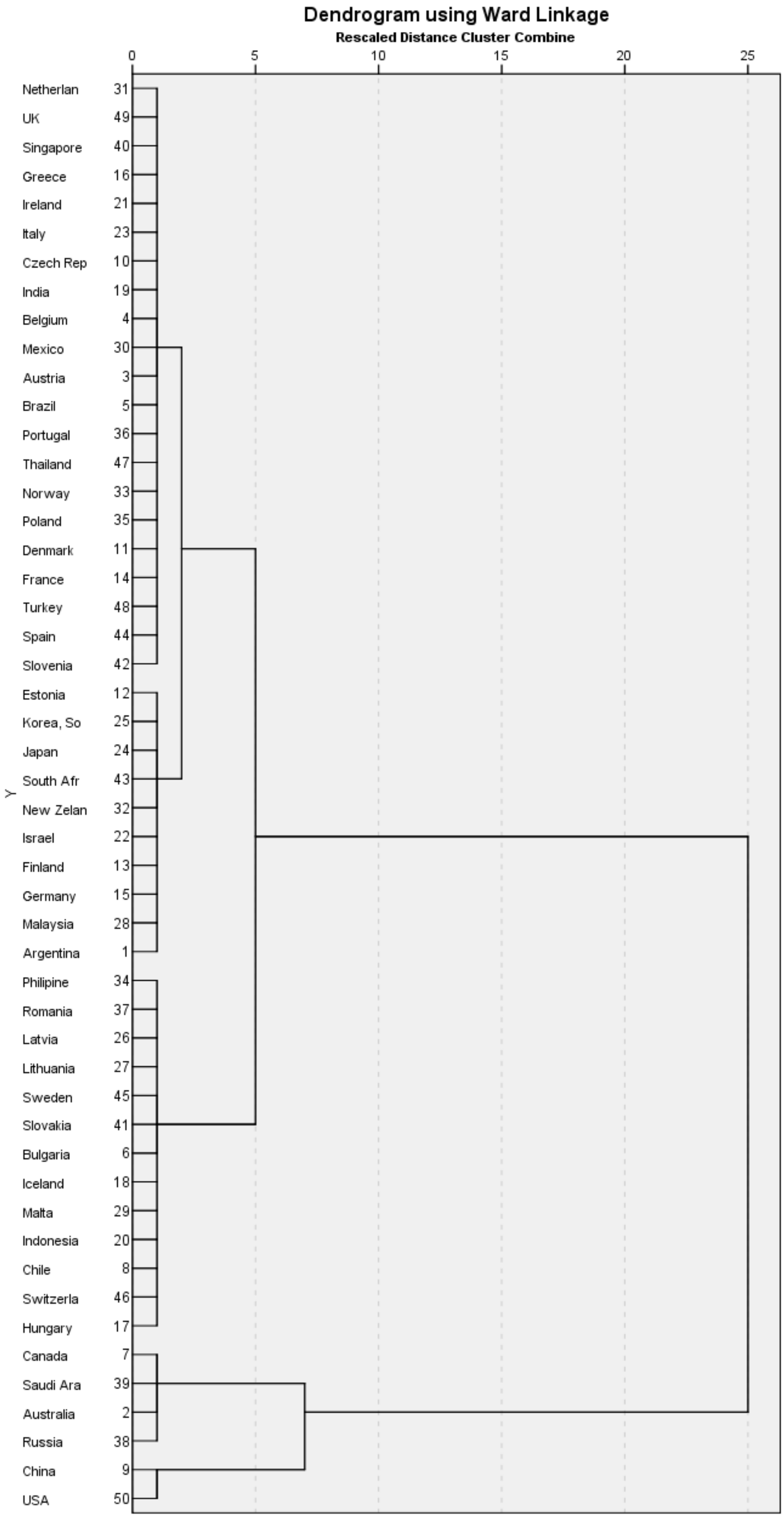

Figure A- 3: Dendogram of Method-1’s CBDR Index

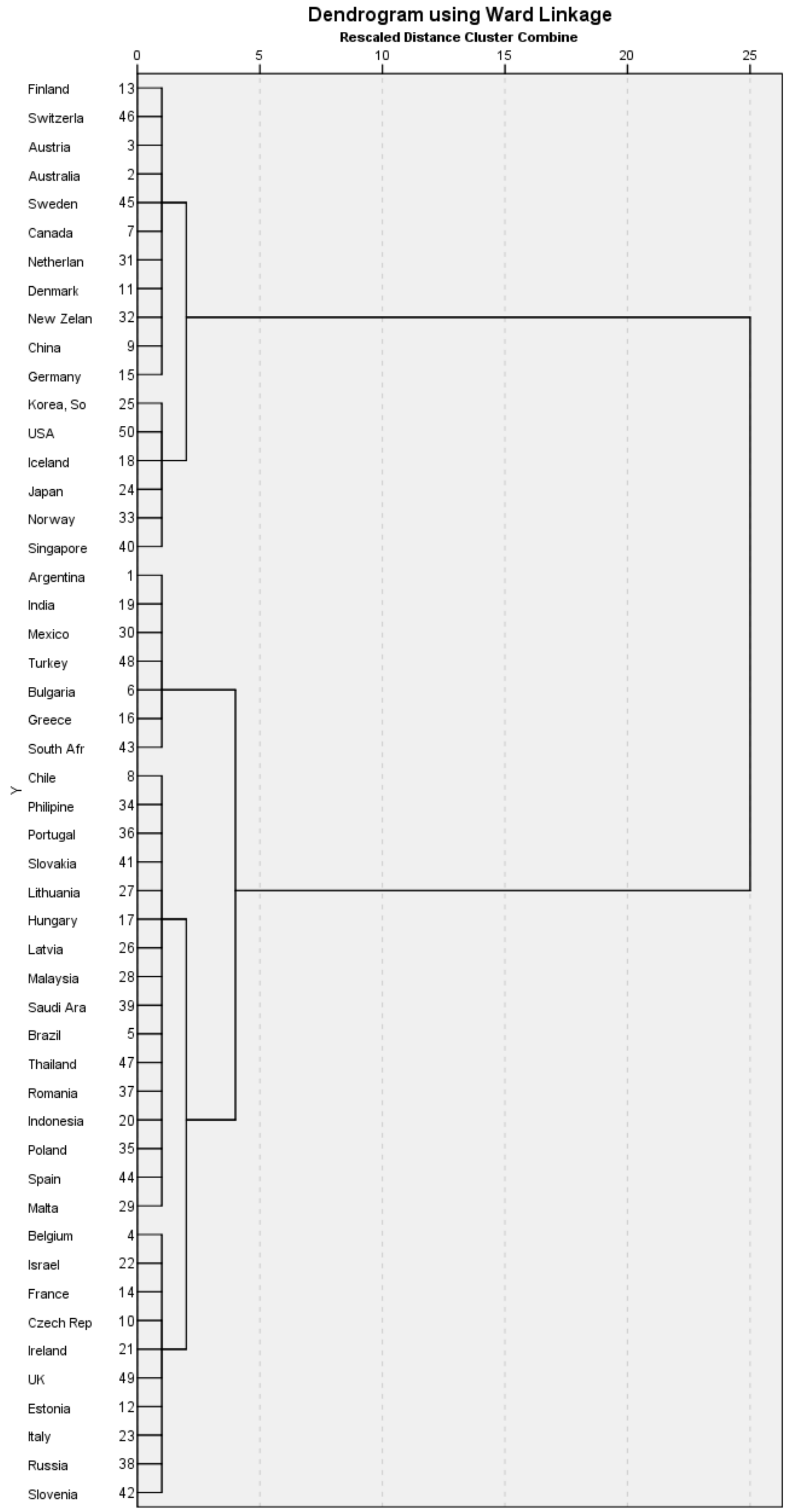

Figure A- 4: Dendogram of Method-1's RC Index

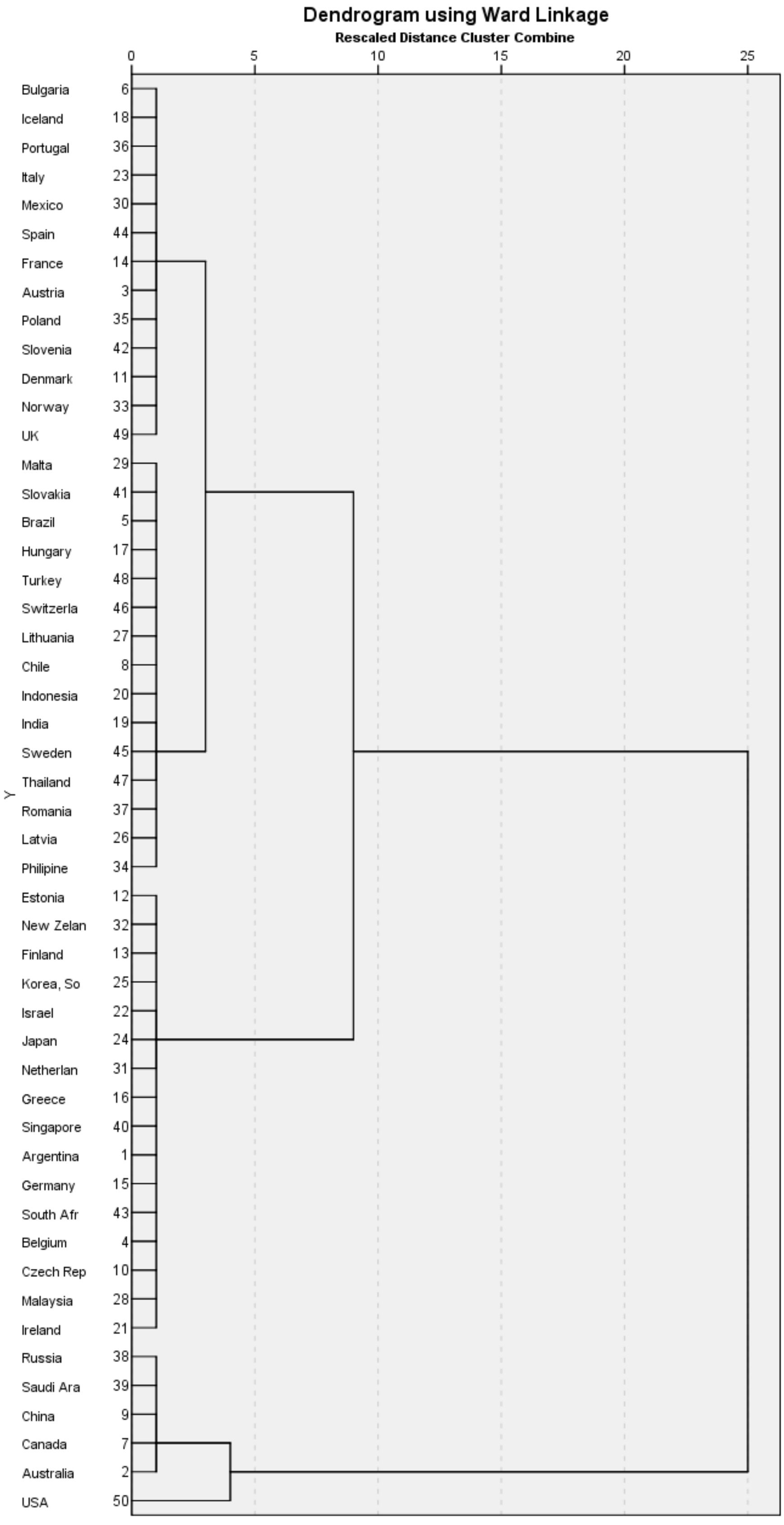

Figure A- 5: Dendogram of Method-2's CBDR Index

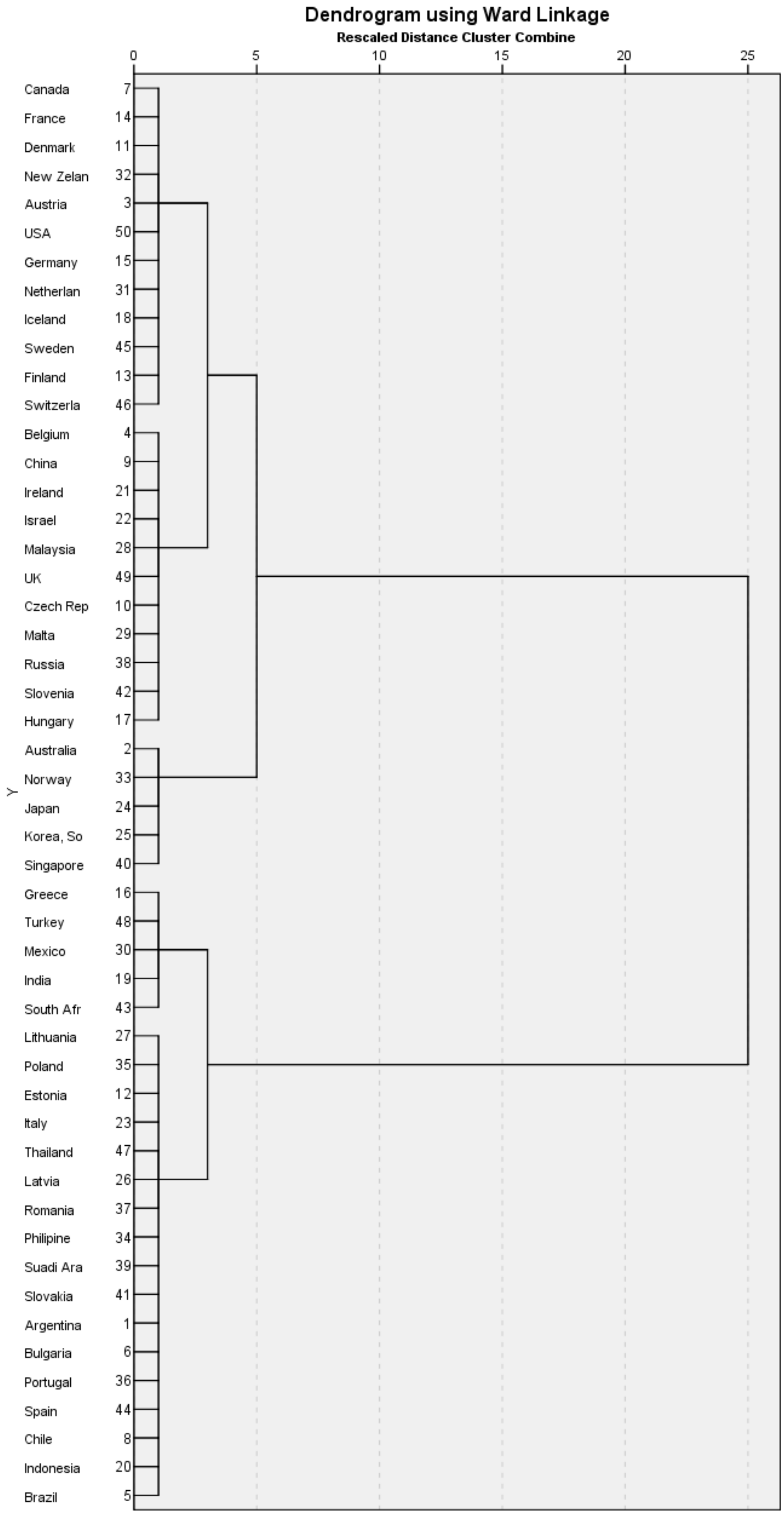

Figure A- 6: Dendogram of Method-2's RC Index

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- Ari I. “Voluntary Emission Trading potential of Turkey”, Energy policy, Vol. 62, 910-919, 2013

Book

- *Emission Trading for Combating Climate Change and Its Implementation In Turkey*, Planning Expertise Thesis, State Planning Organization, Ankara

- *Historical Development and Economics of Emissions from Energy, Book chapter-3, “Climate Change and Sustainable Development in Turkey”, Eniva, Istanbul, 2013*

Refereed Articles in Conference Proceedings

- Ari, I. and Aydinalp Koksal, M., The Importance of Renewable Energy Sources for Mitigation of GHG Emissions, 5th National Air Pollution and Control Symposium, Ankara, Turkey
- Ari, I. and Aydinalp Koksal, M., “Mitigation of CO2 Emission from Electricity Generation by Using Renewable Energy Sources”, 10th International Conference on Clean Energy (ICCE-2010), September 15-17, 2010, Famagusta, N. Cyprus.
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- *Certificate of Participation in 1st Meteorological Symposium,* 27 -28 May 2010, Ministry of Environment and Forestry of Turkey
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