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CLIMATE CHANGE AND GLOBAL RESPONSIBILITY - THE ROLE OF ENERGY CONSUMPTION, GDP AND CO_2 EMISSIONS

Eeva Kuntsi-Reunanen

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ABSTRACT

Climate change is one of the biggest challenges faced by this generation. Despite being the single most important environmental challenge facing the planet and despite over two decades of international climate negotiations, global greenhouse gas (GHG) emissions continue to rise. By the middle of this century, GHGs must be reduced by as much as 40-70% if dangerous climate change is to be avoided.

In the Kyoto Protocol 1997, no quantitative emission limitation and reduction commitments were placed on the developing countries. For the planning of the future commitment period and possible participation of developing countries, information of the functioning of the energy systems, CO_2 emissions development in different sectors, energy use and technological development in developing countries is essential. In addition to the per capita emissions, the efficiency of the energy system in relation to GHG emissions is crucial for the decision of future long-term burden sharing between countries.

Country's future development of CO_2 emissions can be defined by the estimated CO_2 intensity and GDP growth in the future. The changes in CO_2 intensity depend on several factors, but generally developed countries' intensity has been increasing in the industrialization phase and decreasing when their economy has shifted towards the system dominated by the service sector. The level of the CO_2 intensity depends by a large extent on the production structure and the energy sources that are used.

Currently, one of the most urgent issues regarding global climate change is to decide the future after the Kyoto Protocol. Negotiations on this topic have already been initiated, with the aim of being finalised by the end of 2015. This thesis provides insights into the various approaches that can be used to characterise the concept of comparable efforts for developing countries in a future international climate agreement.

The thesis examines the post-Kyoto burden sharing questions for developing countries concentrating to the contraction and convergence model, which is one approach that has been proposed to allocate commitments regarding future GHG emissions mitigation. This further developed approach is a practical tool for the evaluation of the Kyoto climate policy process and global climate change negotiations from the perspective of the developing countries.

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Keywords: climate change, CO_2 emissions, CO_2 intensity, energy use, developing countries, burden sharing, future targets, contraction and convergence

TIIVISTELMÄ

Ilmastonmuutos on yksi suurimmista sukupolvemme kohtaamista haasteista. Vaikka kasvihuonekaasupäästöt ovat kaikkein huomattavin yksittäinen ympäristöä uhkaava tekijä, ja vaikka niiden rajoittamisesta on käyty kansainvälisiä neuvotteluita jo yli kahden vuosikymmenen ajan, päästömäärät jatkavat siitä huolimatta kasvuaan maailmanlaajuisesti. Kasvihuonekaasupäästöjä on vähennettävä tämän vuosisadan puoliväliin mennessä jopa 40–70 prosenttia, jotta vaarallinen ilmastonmuutos voitaisiin välttää.

Kioton sopimuksessa 1997 ei asetettu määrällisiä päästörajoituksia kehitysmaille, eikä niitä vaadittu sitoutumaan päästövähennyksiin. Jotta tulevaa velvoitekautta ja kehitysmaiden mahdollista osallistumista voitaisiin suunnitella, kehitysmaille tulee tarjota tietoa energiajärjestelmien toiminnasta. Kyseisissä maissa on lisäksi edistettävä hiilidioksidipäästöjen vähentämistä eri sektoreilla sekä panostettava teknologian kehittämiseen ja energian käytön tehostamiseen. Tehtäessä päätöksiä tulevien pitkän aikavälin velvoitteiden jakamisesta maiden kesken on otettava huomioon päästömäärät henkilöä kohti sekä erityisesti energiajärjestelmän tehokkuus suhteessa kasvihuonekaasupäästöihin.

Maiden hiilidioksidipäästöjen tuleva kehitys voidaan määritellä arvioidun hiilidioksidi-intensiteetin sekä bruttokansantuotteen tulevan kasvun avulla. Hiilidioksidi-intensiteetin muutokset riippuvat useista tekijöistä. Yleisesti ottaen kehittyneiden maiden hiilidioksidi-intensiteetti on kasvanut teollistumisen aikana ja pienentynyt, kun niiden talous on painottunut enemmän palvelusektorille. Hiilidioksidi-intensiteetin taso riippuu suuresti tuotantorakenteesta sekä käytetyistä energianlähteistä.

Tällä hetkellä yksi polttavimmista ilmastonmuutokseen liittyvistä päätöksistä koskee Kioton sopimuksen tulevaisuutta. Neuvottelut ovat jo käynnissä, ja ne on tarkoitus saada päätökseen vuoden 2015 aikana. Tässä väitöskirjassa tarkastellaan erilaisia lähestymistapoja, joita voidaan käyttää luonnehtimaan, mihin vertailukelpoisiin toimiin kehitysmaat voisivat osallistua tulevassa ilmastosopimuksessa. Väitöskirjassa pohditaan kehitysmaita koskevien velvoitteiden jakamiseen liittyviä kysymyksiä, jotka tulevat ajankohtaisiksi, kun Kioton sopimus umpeutuu.

Väitöskirjassa tarkasteltua vähennä ja lähennä -mallia on ehdotettu yhdeksi lähestymistavaksi, jonka avulla voitaisiin kohdentaa kasvihuonekaasupäästöjen tulevaan vähentämiseen liittyvää sitoutumista. Tämä entisestään kehitelty lähestymistapa on käytännönläheinen työkalu Kioton ilmastosopimusprosessin sekä kansainvälisten ilmastoneuvotteluiden arvioimiseen kehitysmaiden näkökulmasta.

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Avainsanat: ilmastonmuutos, hiilidioksidipäästöt, hiilidioksidi-intensiteetti, energian käyttö, kehitysmaat, velvoitteiden jakaminen, tulevaisuuden tavoitteet, vähennä ja lähennä

ACKNOWLEDGEMENTS

To my dearest family.

Running in circles
Coming up tails
Heads on a science apart

Nobody said it was easy
It's such a shame for us to part
Nobody said it was easy
No one ever said it would be this hard

Oh, take me back to the start

I was just guessing
At numbers and figures
Pulling the puzzles apart

Questions of science
Science and progress
Do not speak as loud as my heart

The Scientist - Coldplay

At first glance in my worst scenario I never imagined that my doctoral path would be such a long journey. In the same year that I started my academic career and began to play with numbers and models, the Scientist song was published. In 2002, the lyrics made me laugh, but ever since I have really felt like that: Always coming back to the roots. Even though the lyrics tell the story of a man's desire to love and apologise, I felt that this was talking about my relationship: not with a man, but with science. The lyrics try to analyse a broken relationship, between my research and me. Essentially, ups and downs are included in every research project; every now and then I even thought that this was not my path at all.

Luckily, I realised pretty soon that I am not alone in the academic world having that frustrated feeling. However, even in an empty academic world, I felt like one of them: I belong in this weird group of scientists. And that kept me going: Strong and more or less motivated. I was eager enough to battle myself to reach the highest degree. Even though and sadly during the journey I have lost some great scientists.

In memoriam:
My colleague, who always believed in me, doctor JiWu Sun
My supervisor, who always challenged me, professor Mika Widgrén
My colleague, who never doubted me, doctor Anita Rubin
My manager, who always supported me, rector Tapio Reponen

Years passed by. Fortunately, along this journey I also had the greatest moments in my whole career. The feeling of victory when my first article was published in a high standard international journal, followed by a biographical profile in Who's Who in the World. Among other highs, these propelled me forward for another bunch of years.

The research process of this thesis originates from 2002 when I left my post at the Ministry of Labour and joined the Academy of Finland's SEDCO research project. That was managed by Jyrki Luukkanen, who was my first supervisor. Luukkanen's contribution as a supervisor and co-author was essential during the first era of the PhD project. Receiving a post as a researcher at the Finland Futures Research Centre (FFRC) gave me the opportunity to work with my research. I wish to thank my former bosses Markku Wilenius and Juha Kaskinen at the FFRC for their kind support. Very special thanks go to Pete Tapio and JiWu Sun. They made me feel adept and never impugned my research. I also had pleasant and memorable 'discussions' with Anne Arvonen and Anne-Mari Vilola, not to forget the therapy sessions with former fellow researchers Nina Aarras and Kirsi Kallio.

Working for the Turku School of Economics for more than ten years gave me the opportunity to be Paavo Okko's apprentice. I was lucky enough to have a supervisor with a heart, who took care of me as a whole, as a person, not just as a researcher. Kind regards to him: I always honoured him. During my postgraduate studies in economics, my supervisors regularly changed, among them Mika Widgrén, who really challenged me, and Hannu Vartiainen, who kindly helped me.

Besides my thanks to Okko, it is difficult to find the words to sufficiently thank my latest and last supervisor Jukka Käyhkö. I really needed that unmatched talent for constructive encouragement. I would never have completed this thesis without Käyhkö's support. Special thanks to supervisor Jussi Jauhiainen for his valuable comments and accurate advice. I also express my gratitude to the pre-examiners, professor Markku Tykkyläinen and professor Kalev Sepp, for their supportive and corroborative comments.

Looking back, I also want to express my appreciation to my former colleagues and boss at the Ministry of Labour. Matti Sihto, Pekka Tiainen and Anssi Paasivirta: With your example and support, you kicked me from the official working life to the academic world. The salary more than halved, though.

And way back to my undergraduate degree in Manchester: Kevin Tinsdale and Wenda Zhang, you introduced me to the world of economics. Furthermore, during my graduate degree in Strathclyde, Ronald MacDonald and Roger Perman, you were my role models as academics.

Throughout these years, some of my friends have managed to stick with me. I really appreciate it. Thank you all. Not to forget my sisters and family. I was lucky enough to be born into a caring and lovely family. I have a very strong bond with my sisters. They mean the world to me. Likewise our parents, as they taught us the right values of life and raised us to be determined to work hard in silence and let the success be the noise. Thank you for making me what I am.

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Even if it took me on a path that was much longer and more winding than I expected, it was a great hobby, counterbalance and brainwork to be the mother of three. Above all, a doctoral thesis is a nice merit, but I guess I succeeded in this other area of life so much better. At least, it gives me so much more in life.

Now, looking back, it really does not matter that it took a few more years than I expected. The greatest of all is the future, referring now to my own little ones. And a big one, too. Science matters but there is no future for me without love and caring. Love is the greatest. Being loved. Being blessed. With or without science and questions.

Turku, Finland, November 2015

Eeva Kuntsi-Reunanen

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PUBLISHED ARTICLES

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Sun, J.W. and Kuntsi, E. (2004). Environmental impact of energy use in Bangladesh, India, Pakistan and Thailand. Global Environmental Change 14: 161-169.

Article II
Kuntsi-Reunanen, E. (2007). A comparison of Latin American energy-related CO_2 emissions from 1970 to 2001. Energy Policy 35: 586-596.

Article III
Kuntsi-Reunanen, E. and Luukkanen, J. (2007). Target options of burden sharing in developing countries: Defining alternative models of global responsibility. The International Journal of Environmental, Cultural, Economic and Social Sustainability 2 (5): 187-193.

Article IV
Kuntsi-Reunanen, E. and Luukkanen, J. (2006). Greenhouse gas emission reductions in the post-Kyoto period: Emission intensity changes required under the 'contraction and convergence' approach. Natural Resources Forum 30: 272-279.

1 INTRODUCTION

1.1 The climate change challenge

A well-known British economist and academic Nicholas Stern stated in his "Stern Review on the Economics of Climate Change" for the British government in 2007 that "[climate change is] the biggest market failure the world has ever known" (Stern, 2007). There is hence little doubt that climate change is one of the major challenges confronting humanity today. Also as referred by the ex-Vice President of the United States and Nobel Peace Prize laureate Al Gore, the world is in a "state of emergency" (Gore, 2007).

The possibility of human induced climate change due to the increased concentration of greenhouse gases (GHG) in the atmosphere caused by burning fossil fuels, was first discovered by the Swedish scholar Svante Arrhenius in 1896. Regular measurements of the carbon dioxide concentrations initiated in the late 1950's in Mauna Loa, Hawaii, by Charles David Keeling demonstrate that the annual average has risen from 316 ppm in 1959 to 396 ppm in 2013. The full graph (Figure 1.) shows the long sweep from 1958 till today's readings skirting around 400. Actually, recorded single-day concentrations exceeded 400 ppm on March 12th, 2014. In February 2015, the monthly average was 400.30 ppm whereas in September 2015, it was 397.1 ppm. The Mauna Loa CO_2 record is a saw-tooth pattern, with CO_2 concentrations typically falling from May through September, and rising over the rest of the year. This cycle is caused by the natural exchanges of CO_2 with vegetation and soils. Each year, the values are higher than the year before, and this represents an average annual growth rate of 1.4 ppm per year (Robert Monroe, www.scripps.ucsd.edu).

The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012, when multiple independently produced datasets exist. Global mean temperatures are projected to increase by between 1.5 °C and 4.8 °C by 2100 and to continue to rise long after that because of the long residence time of CO_2 in the atmosphere (IPCC, 2013).

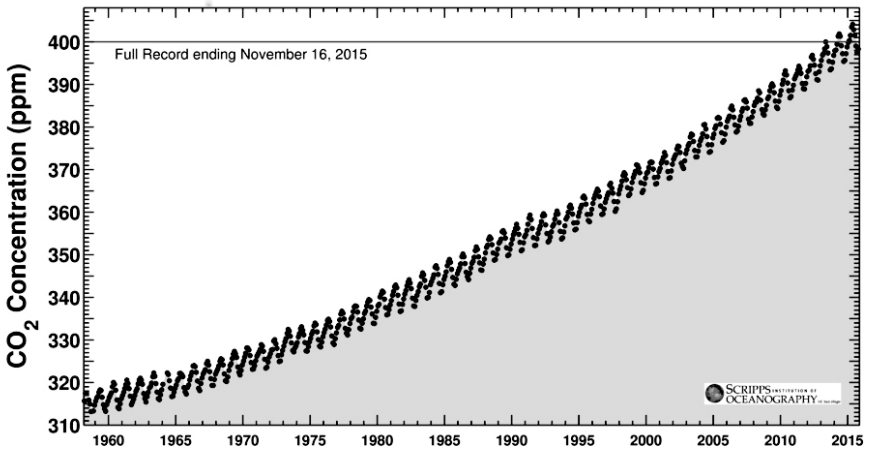

Figure 1. The Keeling Curve shows concentration of atmospheric CO_2 at Mauna Loa since measurements began in 1958. The saw-tooth nature of the curve reflects the annual cycle of seasonal differences in CO_2 release of ecosystems. *Source: Scripps Institution of Oceanography, 2015.*

Despite being what some argue the single most important environmental challenge of the planet, only a handful of states have stabilized or declined their GHG emissions (Schreurs, 2012). Consequently, global GHG emissions continue to rise. The Intergovernmental Panel on Climate Change (IPCC) states that by the middle of this century, GHG emissions must be reduced by as much as 40–70% if dangerous climate change is to be avoided (IPCC, 2013).

Climate change is caused not only by higher GHG concentrations, but a variety of natural and anthropogenic driving forces affecting the global energy balance, including e.g., land use changes and aerosol emissions. Climate change policy requires both mitigation activities designed to reduce GHG emissions, and adaptation policies addressing changes to natural eco- and climatic- systems caused by climate change. Climate change is thus linked to virtually all aspects of modern economics: electricity consumption, heating and cooling of buildings, transportation, agriculture, forestry, waste management, use of chemicals, industrial production processes, etc. Climate change, moreover, impacts biodiversity systems, contributes to water scarcity problems, and sea level rise. Climate change is thus, very much a core sustainability issue (Schreurs, 2012; VijayaVenkataRaman et al., 2012; IPCC, 2013; Nelson, 2013; Rezai et al., 2013; Nielsen and D´haen, 2014).

There are basically three options for the reduction of CO_2 emissions; (i) reduction of carbon intensive energy use, (ii) fuel switch to less carbon intensive

fuels or (iii) efficiency improvement of the energy system (Kuntsi-Reunanen, 2007, hereafter referred to as Article II). The efficiency improvement is related to (i) the socio-cultural development of the society, (ii) economic and structural development and (iii) technological development (Sun and Kuntsi, 2004, hereafter referred to as Article I). Within the economic development, it is essential how the role of industrial development and its structure in the globalised economy (e.g. shift of heavy and polluting industry to developing countries) relates to the development of other sectors (e.g. service sector and tourism) (Article I; Article II).

For the planning of the subsequent commitment period and possible participation of developing countries, information of the functioning of the energy systems in developing countries is crucial. In addition to the per capita emissions, the efficiency of the energy system in relation to GHG emissions is important for the decision of future long-term burden sharing between countries.

The energy use and emissions of developing countries contribute even more strongly in the global climate change (Article I; Kuntsi-Reunanen and Luukkanen, 2006, hereafter referred to as Article IV; Article II; Anderson and Bows, 2011; Akhmat et al., 2014). However, the historical responsibility cannot be laid on them. It is necessary to develop methods to analyse and determine the participation and burden sharing for the different countries based on principles of equity.

It has been very difficult to establish an international agreement about climate change for various reasons. Climate change is characterised by large uncertainties, time lags, and large differences in costs and benefits around the world. Furthermore, climate change impacts a number of properties that are difficult to value, including ecosystems, biodiversity, and quality of life, and it has not been possible to establish meaningful and reliable economic estimates of climate change damages. The estimated benefits of substantially reducing GHGs are diffuse across the globe, uncertain or unknown in terms of probability and magnitude, and primarily fall far in the future (Gupta et al., 2003; Halsnæs and Olhoff, 2005; Desjardins, 2013; García de Jalón et al., 2013; Rosen and Guenther, 2015).

According to Tubi et al. (2012), the failure of international mitigation efforts so far, despite the widespread attention they gained, indicates that climate change is a politically difficult problem to address. Furthermore, it is a global problem, whose solution cannot be achieved through the efforts of any single state or small group of states (Young, 2011). In addition, the negative effects of climate change are largely long term, and therefore are not readily perceptible at present. Hence, mitigation policies imply that present generations pay for the benefit of future generations. Mitigation requires large-scale behavioural changes, but in many cases governments lack the incentive or ability to bring them about. Thus, while collective action is needed to tackle climate change, all countries have a dis-

incentive to undertake such action as they currently enjoy advantages from the activities that contribute to global warming, but will suffer only a fraction of the environmental costs in the future (Anderson and Bows, 2011; Rosen and Guenther, 2015).

1.2 Political processes of climate change

As a political process, climate policy has been around just over four decades. The first United Nations (UN) conference on the human environment was held in Stockholm in 1972. Climate change hardly registered on the agenda, which centred on issues such as chemical pollution, atomic bomb testing and whaling. The United Nations Environment Programme (UNEP) was formed as a result (Johnson, 2012). The next important step seemed to be the first "World Climate Conference" organised by the UNEP and the World Meteorological Organisation (WMO) in Geneva 1979. It expressed concern that continued expansion of man's activities on Earth may cause significant extended regional and even global changes of climate. It called for global cooperation to explore the possible future course of global climate and to take this new understanding into account in planning for the future development of human society (Zillman, 2009).

1.2.1 International response to climate change

A critical point in getting climate change on the international politics agenda was made by the Brundtland commission, a group led by the former Norwegian prime minister Gro Harlem Brundtland. The term *sustainable development* was popularized in *Our Common Future*, a report published in 1987. Also known as the Brundtland report, *Our Common Future* included the definition of sustainable development: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs." (Our Common Future, 1987)

In the following year, the United Nations General Assembly, together with WMO, decided to establish the Intergovernmental Panel on Climate Change (IPCC) to collate and assess evidence on climate change. The purpose of IPCC was to provide international scientific assessment of the magnitude, timing and potential environmental and socio-economic impact of climate change and realistic strategies. The first assessment report (FAR) of IPCC was published in 1990, securing IPCC a primacy position in climate change and climate policy discussion (IPCC, 1990; Zillman, 2009).

Institutional actors play a major role in the formation of international climate change politics. IPCC offers the scientific basis for decision making. The international community accepted global climate change as a major threat to society with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC). This treaty was agreed at the Rio Earth Summit in 1992 (United Nations Framework Convention on Climate Change, 1992b).

1.2.2 Negotiation rules under the United Nations Framework Convention on Climate Change (UNFCCC)

Countries negotiate on climate change as sovereign states under the UNFCCC. It is a system, which is based on voluntary cooperation. Thus, there are no enforcement mechanism other than political pressure that can assure a country to negotiate or to bound by an agreement and consequently agree with its commitments. Therefore, a country will only take on a commitment that it considers reasonable (Yamin and Depledge, 2004).

The main objective of the UNFCCC, which came into force in 1994 and has now been ratified by 195 countries, is the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system as stated in the Article 2 of the UNFCCC: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (United Nations Framework Convention on Climate Change, 1992b).

To reach this objective, the Convention sets out a series of commitments. The adequacy of these commitments will be periodically reviewed in light of the objective of the treaty, new scientific findings, and the effectiveness of national climate change programmes. As a framework treaty, the Convention sets out principles and general commitments, leaving more specific obligations to future legal instruments. In other words, the establishment of the concrete measures whereby national climate policies would be implemented was left to national decision makers.

The UNFCCC established more specific obligations or commitments regarding certain categories of countries. It distinguished between members of the OECD countries, countries in transition to market economy, and developing countries.

The Convention required the OECD countries to take the strongest measures, while the countries in transition are allowed certain leeway (Yamin and Depledge, 2004).

1.2.3 The Kyoto Protocol and its current commitments

The Kyoto Protocol was adopted in 1997, and it added new commitments for developed countries. It also confirmed the general commitments from the Convention for developing countries. In the Kyoto Protocol, the reduction commitments of GHGs were given to industrialised countries (Annex 1 Parties) only. A key feature of the Protocol, which entered into force on the 16th of February 2005, is that it included legally binding GHG emissions targets for Annex 1 Parties totalling a reduction of 5.2% of 1990 levels by the average of emission levels over the five-year period from 2008 to 2012 (United Nations Framework Convention on Climate Change, 1997a). Under the agreement, different countries took on different GHG emission reduction (and in some case growth limitation) targets (e.g., EU -8%, the USA -7%, Canada and Japan -6%, see Table 1). Developing countries could also ratify the agreement and participate in its flexibility mechanisms, for example, the Clean Development Mechanism. This is a system where developed countries can obtain certified credits for emission reduction activities in developing countries and count them towards their own emission reduction targets (Schreurs, 2012).

Table 1. Required changes in GHG emissions from 1990 to the period 2008-12 for selected Annex I Parties.
Source: United Nations Framework Convention on Climate Change, 1997a.

Country	2012 Emission Reduction Target under the Kyoto Protocol (%)
Canada	-6
EU-15	-8
Finland	0
France	0
Germany	-21
Greece	+25
Italy	-6.5
Japan	-6
New Zealand	0
Russian Federation	0
United Kindgom	-12.5
United States	-7
Annex I Kyoto Protocol Parties	-5

1.2.4 IPCC assessment reports and the political process

In 1990, the first assessment report (FAR) of the IPCC concluded that temperatures have risen by 0.3–0.6 °C over the last century. It also stated that humanity's emissions are adding to the atmosphere's natural complement of GHGs. Therefore, it concluded that this addition would be expected to result in warming (IPCC, 1990).

The second assessment report (SAR) was published in 1996 (IPCC, 1996a; IPCC, 1996b; IPCC, 1996c). A cautious analysis of the difference between the human effect and the natural variation of radiative forcing was made. And thus, this was the first authoritative statement that humans are responsible for climate change. In some calculations, the SAR suggested a reduction target of over 60%, aimed at stabilising the CO_2 concentrations at 450 ppm until the year 2100 (IPCC, 1996a).

The IPCC third assessment report (TAR) found even stronger evidence that anthropogenic GHG emissions are the main cause of the warming since the mid-20th Century (IPCC, 2001a; IPCC, 2001b). In the TAR and the Special Report on Emissions Scenarios (IPCC, 2000), IPCC introduced possible emission scenarios (SRES scenarios) and their resulting effects on the climate under the assumption that no additional measures specifically targeted to climate change would be implemented. CO_2 concentrations in 2100 were estimated to range from 500 to 900 ppm (Figure 2). Scenario families contain individual scenarios with common themes. The six families of scenarios discussed in TAR are A1FI, A1B, A1T, A2, B1 and B2 (IPCC, 2000).

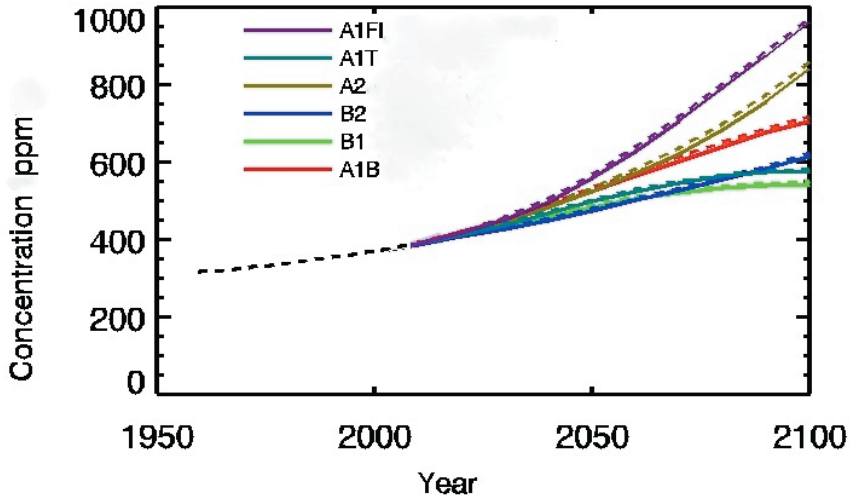

Figure 2. Observed atmospheric CO_2 concentrations 1958–2008 and projected concentrations after various illustrative SRES scenarios until 2100. *Source: IPCC, 2001.*

The fourth assessment report (AR4) in 2007 stated that global atmospheric GHG concentrations increased *evidently* as a result of human activities. The report concluded that it is more than 90% likely that GHG emissions by the humans are responsible for climate change. In 2005, the CO_2 concentration exceeded by far the natural range over the last 650,000 years (IPCC, 2007).

The fifth assessment report (AR5) was finalised in 2014. The first document of the report, the Final Draft of the Working Group I, was released in September 2013. According to the report, it is *highly likely* that human influence has been the dominant cause of the conserved warming in the second half of the 20th century. The evidence for this has grown, thanks to more and better observations, an improved understanding of the climate system response and improved climate models. Compared to the previous reports, the lower bounds for the sensitivity of the climate system to emissions were slightly lowered. The global surface temperature change by the end of this century is expected to be probable to exceed 1.5 °C relative to 1850 to 1900 in all but the lowest scenario considered, and probable to exceed 2 °C for the two high scenarios (IPCC, 2013). The key finding of the Synthesis Report (SYR) of the AR5 is that remaining below the 2 °C target will require that GHG emissions decline by 40–70% by 2050, relative to 2010 levels, and reach zero or negative levels by 2100 (IPCC, 2014).

Findings of the AR5 are based on a new set of scenarios that replace the SRES scenarios of the previous reports. These new scenarios are called Representative Concentration Pathways (RCPs), referring to the amount of increase in radiative forcing (W/m^2). The RCPs describe 4 different scenarios based on different assumptions about population, economic growth, energy consumption and sources, and land use over this century. The GHG concentrations in the RCPs closely correspond to the emissions trends discussed earlier (Figure 3).

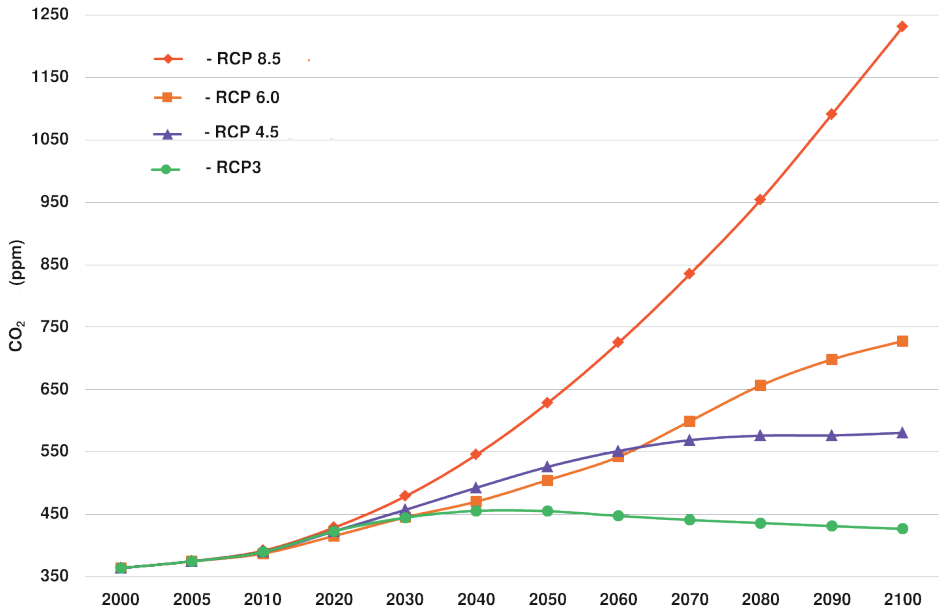

Figure 3. Future CO_2 concentrations in the atmosphere under the four RCP scenarios. *Source: IPCC, 2014.*

RCP8.5 is the highest scenario where atmospheric CO_2 concentrations reach 1230 ppm by 2100 and continue increasing for another 100 years. In RCP6 scenario, CO_2 concentration continues increasing, though at a slower rate in the latter parts of the century, reaching 730 ppm by 2100. RCP4.5 show a stabilizing CO_2 concentration as it continues on trend to about 560 ppm in 2070 and continues to increase but more slowly. Finally, RCP2.6 shows a peak in CO_2 concentration around 2040, followed by a modest decline to around 430 ppm CO_2, by the end of the century. This development requires a major turnaround in climate policies and a start to concerted action in the next few years in all countries, both developing and developed (van Vuuren et al., 2011; IPCC, 2014).

A comparison of the conclusions of the earlier four reports to the in 2013 published AR5 demonstrates that the basic facts of climate change have not changed. Hence, the scientific information has been available for more than 20 years, but the development of political regime has suffered from friction due to lack of mutual understanding of how to reduce the emissions.

1.2.5 Challenges for future cooperation

The current Kyoto protocol commitment targets are not adequate, as scientific evidence calls for 50–70% reduction in GHG emissions in order to keep the rate of warming below 2 °C –a limit of "safe warming" (IPCC, 2013). The key weakness of the Protocol is that it does not include any commitments for developing country parties. In other words, even if the Kyoto targets are met, emissions will continue to rise globally because of the rising emissions in the developing countries (Article II).

It is obvious that avoiding disastrous climate change will require participation of all countries as it is anticipated that the emissions of developing countries will outgrow those of the developed countries. Therefore, one of the main policy issues in the development of the Framework Convention on Climate Change (FCCC) is the participation of developing countries (non-Annex I Parties).

However, developing countries have stressed that because of their historical burden the industrialised countries should take the principal responsibility for the climate problem and be the first to act. This was formally recognised in the FCCC in 1992, as it stated that developing and developed countries have "common but differentiated responsibilities" (United Nations Framework Convention on Climate Change, 1992a). This argument is well created, but it is certain that the ultimate objective of the UNFCCC can only be met if all countries are eventually involved.

Although the simultaneous integration of developing countries in international GHG emission reduction efforts encompasses a number of difficulties, it also offers opportunities (Halsnæs and Olhoff, 2005). On one hand, developing countries claim that climate change in the next century is caused by past emissions from industrialised countries and that these countries therefore have to carry the major burden of GHG emission reduction policies. On the other hand, the future development in GHG emission sources as well as the marginal reduction costs suggests that large low cost reduction option exists in these countries.

In addition to the large global direct cost savings by coordinated policies, the corresponding GHG emission reduction in developing countries would also be associated with large indirect social benefits. The existence of indirect benefits of GHG emission reduction policies in developing countries implies that the scale of the international GHG emission reduction efforts in future global climate change

agreements could be expanded. At the same time, the inclusion of local benefits in developing countries in GHG emission reduction efforts will also create stronger incentives for the countries to participate in international climate change policies (Halsnæs and Olhoff, 2005).

However, international trade creates a geographic separation of consumers and the production of consumer goods pollution. This contributes a mechanism for producers to shift pollution related with consumption to remote countries. For local pollutants this may be viewed as a rational choice for consumers, but for global GHGs, consumers will bear the costs no matter of where production takes place. Therefore, it is important that the optimal policy for global pollutants is to consider the implications of international trade. Better understanding of trade's role in a country's economic and environmental development will help design more effective and inclusionary climate policy post-Kyoto (Peters and Hertwich, 2008).

The Kyoto Protocol suffered a major blow when in 2001 the United States made clear it would not seek to ratify the agreement. For more than a decade, international negotiators have struggled to find a path forward that would more effectively address rising global GHG emissions – either through a revision of the Kyoto Protocol that would require action of both developed and developing countries, or through some new kind of arrangement (Schreurs, 2012).

Currently, one of the most urgent issues regarding global climate change is to decide the future of the Kyoto Protocol. So far, no clear agreement has been reached among parties. It is anticipated, however, that growing evidence of the negative impacts will finally pave the way for a global, legally binding treaty on reducing carbon emissions at the next UNFCCC in Paris in December 2015. One of the most important disputes among parties in the negotiation to save the Kyoto Protocol is how to include the emerging developing countries in a legally binding emission gap. More detailed negotiations are needed to be conducted according to the principle of "common but differentiated responsibilities" in Article 3 of the UNFCCC (United Nations Framework Convention on Climate Change, 1992b), which emphasizes the responsibilities of industrialised countries. Considering the fact that GHG emissions from emerging developing countries are rising significantly and show a growing percentage of the global GHG emissions, the trend to control the GHG emission from these countries is inevitable in the long run (Hu and Monroy, 2012). In order to substantially mitigate global climate change, innovation is needed to create a more effective global cooperation and collaboration framework.

1.3 Research rationale

The central question still remains: How could the commitments in the international emission regime be further developed, so that they prevent dangerous interference with the climate system and at the same time are acceptable to all parties? In the field of climate change research, this academic dissertation in economic geography aims to provide detailed, novel analysis on future international emission regime. On one hand, large uncertainties stemming from ignorance and indeterminacy set a challenge of estimating the accurate effect on future climate change. On the other hand, quantitative comparative results, which take into account the socio-cultural and historical context of the developing countries, will be of great importance in the international climate policy decision-making. There is a need to better understand the relationship between GDP, GHG emissions and energy use in developing countries. This study aims to assess and consider options for the future development of the international climate change regime under the UNFCCC and the Kyoto Protocol. The focus lies on mitigation commitments aimed at reducing GHG emissions. This thesis addresses the following questions:

1) What were the differences of energy use and CO_2 emission intensity in the selected developing Southern Asian countries and Latin American countries in 1970–2001?

2) Based on the above mentioned developing Southern Asian and Latin American countries, what is the cause of the developing countries' changes in CO_2 emissions in 1970–2001?

3) What are the main allocation schemes of international climate policy in the process of finding new agreement for future reduction in the GHGs?

4) What are the key arguments for and against the *contraction & convergence (C&C) approach* in analyzing post-Kyoto CO_2 emission intensities?

These four research questions try to examine the energy and climate sectors in developing countries in a global context. The study provides insights into the various burden sharing proposals that can be used in the concept of equality in emission reductions for developing countries in international climate agreements, including the current COP21 negotiations in Paris.

1.4 Regional case studies

The thesis is concerned with the developing countries' energy and climate policy, with an emphasis on Southern Asian and Latin American countries. These case study regions were selected to illustrate a range of energy sector in different parts of the world. As far as these countries are concerned, they have quite similar characteristics on the structure of their energy economies (Article I; Article II). These comparative results form an important platform also for the least developing countries as climate policy planning is also in the agenda of the countries in Africa (Weston, 2012) and Asia-Pacific. The research will be extended to a comparative study of industrialized countries of the USA, Japan, France, the United Kingdom and Germany. Countries dealt with in the thesis are shown in Figure 4 and listed in Table 2 with the basic information on their economics and related CO_2 emissions in 2001.

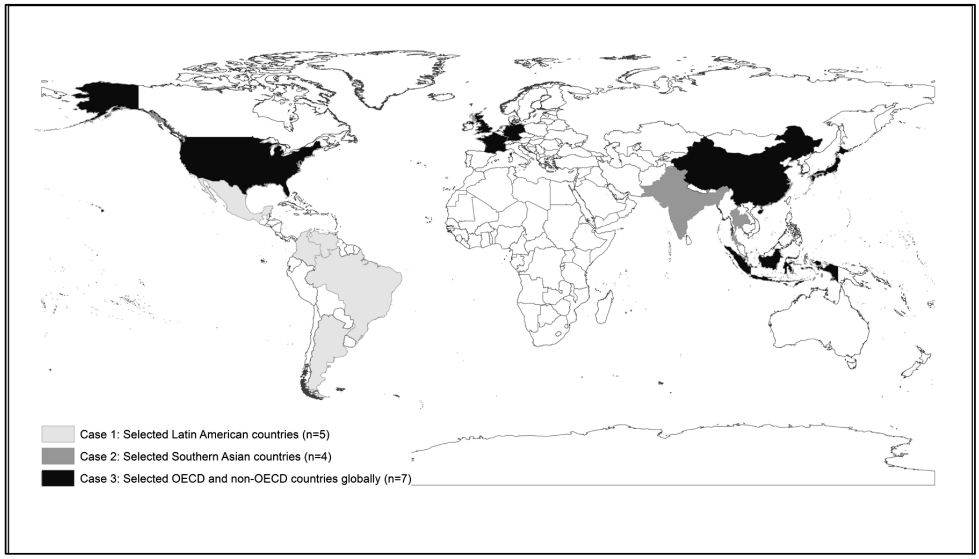

Figure 4. The 16 case study countries. *Source: GIS.*

Table 2. Basic information of economics and related CO_2 emissions of the 16 case study countries in 2001.

Country	POP[a]	GDP[b]	CO_2[c]	CO_2/GDP[d]	CO_2 per capita[e]
Bangladesh	133,35	196	31	0,22	0,3
India	1032,36	2707	1013	0,45	1,2
Pakistan	141,45	240	99	0,52	0,9
Thailand	61,18	357	156	0,58	3,4
Argentina	37,49	386	118	0,3	3,1
Brazil	172,39	1140	312	0,29	1,9
Colombia	43,03	278	56	0,2	1,3
Mexico	99,11	807	359	0,49	4
Venezuela	24,63	130	129	0,99	5,2
United States	285,91	8978	5673	0,62	19,6
United Kingdom	58,79	1293	541	0,41	9,1
Germany	82,34	1922	850	0,41	9,6
France	60,91	1395	385	0,26	6,1
Japan	127,21	3126	1132	0,37	9
China	1271,85	4708	3075	0,62	2,3
Indonesia	208,98	560	384	0,47	1,2

Source: Adapted from IEA (2003a)

[a]Millions

[b]Billions of 1995 US dollars

[c]Sectoral approach (Mt of CO_2)

[d]Tons of CO_2 per 1000 US dollars

[e]Tons

1.5 Structure of the study

This thesis consists of four published journal articles (attachments) plus the summarizing section at hand. In this summary, climate change and post-Kyoto issues including some more general aspects are dealt with in chapter 2. The employed methodology, as well as the positioning of the supporting articles, is defined in chapter 3. The results are presented in chapter 4. The discussion, potential and limitations for future research are revealed in chapter 5. Finally, the conclusions of this thesis are presented in the last chapter.

1.5.1 Article I: The South Asian case

In article I, the environmental impact of energy use is evaluated from the level of the utilization of natural sources as measured by energy intensity and the level of environmental stress as measured by CO_2 emission intensity. The emissions of energy use in four Southern Asian developing countries (Bangladesh, India, Pakistan and Thailand) from 1973 to 2000 are analysed based on the International Energy Agency's 2002 database.

1.5.2 Article II: The Latin American case

Article II deals with the internal dynamics of the development of energy sector in the light of CO_2 emissions. It carries out a comparative analysis of CO_2 emissions and intensity developments for five Latin American countries (Argentina, Brazil, Colombia, Mexico and Venezuela) in years 1971-2001. In addition, country level development of CO_2 emissions and energy use is analysed in these countries.

1.5.3 Article III: The post-Kyoto burden sharing issue

Article III examines the post-Kyoto burden sharing issue. It studies some of the most original and interesting methods and models used in burden sharing proposals. Each of these approaches is evaluated according to the criteria of environmental effectiveness, cost-effectiveness and equity. Alternative methods of how the burden should be shared among nations after the Kyoto Protocol first commitment period are analysed.

1.5.4 Article IV: The contraction and convergence (C&C) approach analysis

Article IV concentrates on the contraction and convergence (C&C) approach, which is based on equal per capita emission rights and concedes individuals' equal right to pollution permits. The article develops C&C approach to a further level and takes GDP into account. The aim of article IV is to analyse what the further developed C&C approach would mean for certain OECD and non-OECD countries.

2 THEORETICAL BACKGROUND

2.1 What makes climate change so special?

Climate change is now a major pre-occupation of many governments. Its profile as a public policy issue is due to both evidence-based reports, such as the Stern review (Stern, 2007) (Box 1.) and its prominence in popular culture that has been mediated through movies and rock concerts. According to Guest (2009), the concern about climate change is a manifestation of a broader social concern about sustainable development.

Box 1. The Stern Review on the Economics of Climate Change.
Source: Stern, 2007.

A 700-page report released for the British government on 2006 by economist Nicholas Stern. The report discusses the effect of global warming on the world economy. Although not the first economic report on climate change, it is significant as the largest and most widely known and discussed report of its kind.

The Review states that climate change is the greatest and widest-ranging market failure ever seen, presenting a unique challenge for economics. The Review provides prescriptions including environmental taxes to minimise the economic and social disruptions. The Stern Review's main conclusion is that the benefits of strong, early action on climate change far outweigh the costs of not acting. The Review points to the potential impacts of climate change on water resources, food production, health, and the environment. According to the Review, without action, the overall costs of climate change will be equivalent to losing at least 5% of global gross domestic product (GDP) each year, now and forever. Including a wider range of risks and impacts could increase this to 20% of GDP or more, also indefinitely. Stern believes that 5–6 degrees of temperature increase is "a real possibility."

The Review proposes that one percent of global GDP *per annum* is required to be invested to avoid the worst effects of climate change. In June 2008, Stern increased the estimate for the annual cost of achieving stabilisation between 500 and 550 ppm CO_2e to 2% of GDP to account for faster than expected climate change.

Climate change is the most challenging political problem the world has ever had to deal with. It is a prisoner's dilemma, a free-rider problem and the tragedy of the commons at the same time (Box 2). Mitigation is hindered by the complexity of distributing the cost of common action and trusting other parties to bear their share of the burden. As stated in Guest (2009), the need for global action is an application of the classic prisoner's dilemma problem. The key issues are the optimal quantum of environmental damage abatement, the best policy instruments to use, and the way in which the global abatement effort should be shared between poor and rich countries (Hackett, 2006).

Box 2. Prisoner's dilemma, Free-rider problem and Tragedy of the commons summarised.
Source: Boersema and Reijnders, 2009.

Prisoner's dilemma	**Free-rider problem**	**Tragedy of the commons**
Prisoner's dilemma is a canonical example of a game analyzed in game theory that shows why two individuals might not cooperate, even if it appears that it is in their best interests to do so. This is also evident in crises such as the global climate change. It is argued that all countries will benefit from a stable climate, but any single country is often hesitant to curb CO_2 emissions. The immediate benefit to an individual country to maintain its current behavior is perceived to be greater than the purported eventual benefit to all countries if behavior was changed, explaining the current impasse concerning climate change mitigation.	Free riders are those who consume more than their fair share of a public resource, or shoulder less than a fair share of the costs of its production. Free riding is usually considered to be an economic problem only when it leads to the non-production or under-production of a public good, or a common property resource. The free rider problem is the question of how to limit free riding in these situations.	The tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently and rationally consulting their own self-interest, will ultimately deplete a shared limited resource even when it is clear that it is not in anyone's long-term interest for this to happen. The concept is often cited in connection with sustainable development, meshing economic growth and environmental protection, as well as in the debate over global warming.

Understanding how humans make decisions and respond to incentives is an interesting academic challenge. It may depict to be the key to the quality of human life. It is evident that responding to rapid climate change will be the biggest challenge that our generation faces in the coming decades.

As stated by Gowdy (2008), most economists dealing with climate change focus on the "rational allocation" problem, that is, finding the most efficient way to allocate a given level of carbon emissions. Economists have had relatively little to say about how to design policies that would enhance international cooperation or about the economic implications of massively substituting non-carbon fuels. Again, the problem is how to reduce sharply, then eliminate CO_2 emissions, not how to theoretically allocate some given amount of carbon (Gowdy, 2008). Moving away from fossil fuel economy requires institutional change, not merely modifying individual behaviour at the margin. The climate change problem arose from the patterns of behaviour that developed as a direct result of cheap energy and the consumer society that grew out this productivity bonanza.

Nowadays, economics has become an unavoidable discipline in the field of climate policy making. From the very beginning of international talks on this issue, up until the most recent discussions on a post-2012 international framework, economic arguments have turned out to be crucial elements of the analysis that shapes policy responses to the climate threat. This can be illustrated by the prominent role of economics in different analyses produced by the IPCC to assess the impact of climate change on society (Maréchal, 2007)

Understanding the economics of climate change is important as global warming produces several distinct economic effects: from decreased productivity of natural resources (e.g. agriculture), to injured to non-managed natural resources (e.g. biodiversity, landscapes, wilderness), from injure to human-built environment (e.g. coastal flooding from rising sea level), to hazards to humans due to extreme weather events. Eventually, increasing GHG emissions are an economic problem. Emissions can be called as externalities, as they can be seen a market failures which affect climate stability. They can also been categorised as a public good with no market or price. Neither they offer proper incentives against overexploitation of the atmosphere. Because of the characteristic of economics, it is possible to estimate and compare people's valuations of different uses of climate resources in different moments. Usually, the most efficient policy is where the net present value of using the atmosphere is maximized, and it distributes rather related benefits and costs. Generally, mitigation policies provide benefits and involve large costs. Actually, both the bizarre of adverse events and of advantages deriving from avoiding them are not well understood. Therefore, benefits and costs are highly uncertain (United Nations Industrial Development Organization, 2008; VijayaVenkataRaman et al., 2012; Bassett and Fogelman, 2013; Fredriksson and Neumayer, 2013; Kahn, 2013; Nelson, 2013; Rezai et al., 2013; Shaw, 2013; Rosen and Guenther, 2015).

The Stern Review concluded that there can be "no doubt" that the economic risks of business-as-usual climate change are very severe (Stern, 2007). The total cost of climate change was estimated to be equivalent to a one-off, permanent 5-20% loss in global mean per-capita consumption today. And the marginal damage cost of a tonne of carbon emitted today was estimated to be around $312. These estimates are high in relation to the previous literature (Dietz et al., 2007).

But the instability of the estimates depends enormously on variables, which can be difficult to predict in the long run. These are e.g. population, productivity growth, technological improvement and patterns of consumption. Sadly, the knowledge of the distribution the benefits and costs of actions is essential for effectively addressing climate change. The complication of the question leads to high information costs. While the general links between GHGs and global warming are accepted by major part of scientists, the extent and impact of regional climate change remain extremely uncertain. Moreover, the macro- and

microeconomic costs and benefits of emission reduction are unknown (Michaelowa, 1998; VijayaVenkataRaman et al., 2012; Rosen and Guenther, 2015).

Unsolved question in the climate change debate still remains: The definition of an equitable engagement (Mattoo and Subramanian, 2012). In other words, which countries should bear the burden, who and which countries are responsible for climate change, who should act first and in response, how to allocate the burden equitable between all parties, and how to undertake a equitable international agreement, which should be capable at the same time to turn out fair at national level?

Climate change exhibits a number of special characteristics as a global pollution control problem. The climate is a public good, as there is no rivalry in consumption, and consumers cannot be excluded. Clean air is enjoyed essentially by all as the public good cannot exclude anyone from sharing in it, and its enjoyment by one person does not diminish the enjoyment of others. Thus, collective actions should be taken at supranational level. In this framework each country has to define the optimal level of emissions in order to deal properly with the present case. Unfortunately there only exist weak political and economic instruments for attaining and maintaining these goals. Actually, countries tend to decide non-cooperatively, according to their own cost-benefit ratio. That is to say, it is far from easy how the international community defines the framework for the needed inter-governmental collective decision-making process. In addition, the political economy of climate change often seems to prove ineffective in fostering of cutting back the GHGs emissions. An extremely troublesome point arises as GHGs concentrations depend on long-term profile of emissions, because GHGs remain in the atmosphere as long as two hundred years, making the estimates of the emissions both highly unpredictable and distant in the future (Wiener, 1999; Altermeyer-Bartscher et al., 2011; Fredriksson and Neumayer, 2013).

2.2 Public choice – whose choice?

According to the rational choice theory (Mueller, 1979; Mueller, 2003), individuals will generally face disincentives to undertake costly efforts to generate public goods, because the provider bears the cost but is able to recoup only a small fraction of the benefits. This generates strong free-riding incentives on others' provision of public goods, resulting in a general failure to provide the level of public goods that all would prefer if they could act collectively. Free-rider incentives in the Kyoto Protocol may be so strong that it pays a country not to participate. From a strict political economy point of view, countries will only enter a voluntary agreement if they receive a net gain from participation (Barrett, 1998).

Voluntary international agreements, such as the Kyoto, are necessary to provide collective goods at the global level in the absence of supranational authorities. When no one in the group of countries worldwide is excluded from the benefit, the free-rider problem occurs as argued by Olson (Olson, 1965). Why should one country reduce GHGs, if another country did it already? Thus, if a country does achieve a higher overall net gain from free riding than from participation, one may expect that Kyoto target levels will not be accomplished (Kuntsi-Reunanen, 2010). Therefore, the transnational characteristic of global climate change implies a concern about free-riding behaviour by countries choosing to avoid costly GHG control efforts, which in turn creates a competitive advantage in terms of international trade. At the same time, the contribution of individual countries to climate change through GHG emissions does not have a significant impact on the climate, implying that only globally coordinated efforts will result in significant gains in the form of avoided climate change (Halsnæs and Olhoff, 2005; Svendsen, 2005; Tompkins and Eakin 2012; Engels et al., 2013).

In this way, climate policy is an up-to-date issue and is becoming increasingly relevant. Usually, economists note that its instruments have not been designed using the results of economic theory. Inefficient instruments such as subsidies or voluntary agreements are used instead of trade in emissions or taxes. On the one hand a single instrument can be often used as directed towards the achievement of several targets – such as emission reduction and the raising of employment – and on the other hand panoply of measures is directed towards the single target of reducing emissions. The degree of international collaboration is rather low despite huge potential cost savings.

The discussion has focused almost exclusively on economic efficiency with occasionally reference to the body politic. To the extent that politics entered, the imaginary politicians were dedicated to finding efficient solutions to environmental problems. If focusing on choosing, the normative assumption of welfare maximization must be replaced with a positive analysis of political choice. With the arrival of the environmental revolution that brought massive government intervention in markets, economists used their new tools to explain political actions, predict outcomes and analyse implications (Yandle, 1999; Jenkins, 2014).

2.3 Complexity of environmental economics

Assuming that when reducing of CO_2 emissions, the improvement of the environmental quality is an international public good. If the price elasticity of demand is low and in the same time the supply is infinitely elastic, the consumers are the ones who have to bear the costs. Accordingly, if price elasticity is high, only a small part of burden of an environmental measure, which increases the

production costs of a good can be passed on to the consumers. Thus, the producers, shareholders, managers as well as workers of these firms, have to bear the costs. Consequently, the resistance to environmental programs might be higher in regions with a high share of producer interests which oppose such a policy, because a higher burden can lead to reduced profits in these regions (Kirchgässner and Schneider, 2003; Ekins et al., 2009).

When competition is global, it is much more difficult for one nation to provide effective protection to its domestic industries. When ordinary people gain accurate, low-cost information on environmental outcomes, rational ignorance is reduced. Public choice suggests that new global environmental issues will replace those faced by smaller regions and nations. But for rent seekers to be successful on a global scale, a global regulatory body is required. Public choice predicts that new efforts will be made to create a governing process that will address environmental issues of global proportions. The intense lobbying at Kyoto to transfer wealth from the industrialised countries to the developing countries foreshadows things to come. On the other hand, the cost of governing a global environment will be so large that the rent seekers may be forced to retreat, and market forces will engage environmental protection (Yandle, 1999; Shughart II and Razzolini, 2001; McNutt, 2002; Kuntsi-Reunanen, 2010).

While climate change is an interconnected global problem where conflicts of interest are international and intergenerational, it remains a geopolitical issue. Cultural frameworks also have a great influence on how people coordinate in this global question (Heyd, 2010). Game theoretical models have been applied to interconnected global problems, including international environmental cooperation. These models provide an elegant formalisation of strategic interactions across the climate negotiations whose application can inform parties' decisions given certain circumstances (Kennedy and Basu, 2014).

Unfortunately, in terms of global climate change agreement, the number of participants is very high. In respect to causes, impacts and costs of climate change, the participation parties are very different among others. Therefore, and due to the lack of sanctions, they all have strong incentives to free-ride. Climate policy will be particularly subject to distortions for the activities of interest groups due to the variety of groups concerned, the global repercussions and the long time-scales involved. Thus, Michaelowa (1998) suggests that public choice theory is suitable for explaining the reality of climate policy. However, as pointed out in Shughart II and Razzolini (2001) public choice warns of the pitfalls encountered when decisions are made collectively. The theory suggests that we should not expect efficiency to be the driving force that determines political outcomes. The greater the political involvement in allocating and managing a given resource, the less efficient the outcomes will be (McNutt, 2002; Kliemt, 2012).

2.4 Post-Kyoto period and future commitments

2.4.1 COP15: Great expectations in Copenhagen

With the end of the Kyoto Protocol's first commitment period, the international negotiations on climate change sputter on. The objective of the UNFCCC in Copenhagen Conference of Parties (COP15) that took place in December 2009 was to reach agreement on a new international legal architecture for addressing anthropogenic climate change post-2012. It failed in this endeavour, producing a political agreement in the form of Copenhagen Accord (CA). The Accord establishes a broad mitigation framework based on the schedules approach under which countries undertake to implement of meet specific mitigation commitments or targets that are registered in schedules.

In Copenhagen both developed and developing countries agreed to submit economy-wide emission targets for 2020 to either reduce their emissions in the case of developed countries, or slow their growth in the case of developing countries (Bodansky, 2010; Schreurs, 2012). The pledges are not legally binding. According to Beccherle and Tirole (2011), the failure of the Copenhagen negotiation to deliver a legally binding commitment to emissions reductions beyond 2012 has multiple origins. First, the lack of measurement and enforcement protocols and of consensus on instruments made it difficult to even design a sustainable agreement. Second, political will was lacking; indeed no draft had been seriously discussed by heads of states prior to the conference. Finally, the negotiation revealed a high level of distrust among countries (Beccherle and Tirole, 2011).

Carter et al. (2011) argue that the impasse over tackling climate change at the 2009 summit is a result of the outcome of the prevailing power and politics at the summit. In the environmental domain where more states have a voice, as became clear in Copenhagen, the dominant players brought enough bargaining power to the table to ensure that no global deal went through that might damage their interests. The CA is marked by the absence of long-term emission targets, the omission of watertight pledges on new funding, and no clear indications of how to turn the Accord into a legally binding treaty. The big emitters – the US, China, India and the countries of the EU – will continue to be able to act without a binding framework to enforce emission reductions and speed up the pace of a transition to a low-carbon economy.

Although the Copenhagen summit was a drawback for the international community, the outcome was expected since it was near-impossible for the USA to accept significant commitments without prior endorsement by the Senate of climate policy bills under discussion, and equally important, without the

willingness of developing countries like China and India to participate in a binding Protocol (Kypreos, 2012).

In spite the objective difficulties the negotiating parties at Copenhagen including China and India did reach the informal agreement documented in the CA, going in several complementary directions: first to combat global warming assuming differentiated reduction targets in terms of either GHG emissions and/or of energy intensities; and second in having the developed countries mobilizing significant resources supporting green technology and adaptation projects in developing countries. Third, it was decided to "enhance action on development and transfer of technology by establishing a Technology Mechanism in support of action on adaptation and mitigation". Stated also by Kypreos (2012), the COP15 was concluded with at least a modest but promising CA instead of a binding agreement.

The Copenhagen summit reveals it is possible to achieve consensus on the dangers of climate change but it is difficult to translate this in to meaningful action (Bodansky, 2010). The institutional and discursive failures of the summit mean that while securing consensus on climate change is essential it is even more distant in most developed economies, where polls show a steady decline in support for action on climate change in terms of mechanisms such as carbon tax. The democracies have variable capacities to organize a reconfiguration of interests nationally and the assemblies in which these nations, and the rest of the world, meet lack the political means to organize it at present. Hence, existing democratic institutions exacerbate the problem both at the global and national levels. Concluded by Carter et al. (2011), despite its basis in scientific research climate change is more of a political than a scientific problem: as an essentially discursive matter we need a better vocabulary for organizing interests, rather than a better science.

2.4.2 COP16 and COP17: Little success in Cancun and Durban

Also the subsequent COP16, that took place in Cancun, Mexico in December 2010, endorsed and complemented the CA, but the deadlock in climate change negotiations remains due to inability of the parties to arrange a post-Kyoto agreement. At the 16th COP agreements were only reached on mechanisms for technology transfer and an adaptation fund. There was little expectation that a successor agreement to Kyoto would be reached in Durban, South Africa at the 17th COP in December 2011. In fact, agreement was reached to extend the Kyoto Protocol for a second commitment period that is to last until the end of 2017 or 2020 and that will aim to reduce GHG emissions of Annex I emissions by 25–40% of 1990 levels by 2020. But the agreement now really only covers European

countries, New Zealand, and Australia given that Canada, Japan, and Russia made clear they has no intention of agreeing to a second commitment period under the Kyoto Protocol. Thus, the Kyoto Protocol lives on, but greatly narrowed in scope, and certainly insufficient to make much of a dent in global GHG emissions (Schreurs, 2012).

The second agreement reached in Durban was to keep negotiating on a future agreement. The negotiators agreed "to launch a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the UNFCCC applicable to all Parties." According to Schreurs (2012) what this means is that in contrast with the Kyoto Protocol, which set emission targets only for developed countries, any new agreement is to cover both developed and developing countries. The agreement, called Durban Platform for Enhanced Action, has as its goal to keep temperature increases to 1.5 to 2 °C above pre-industrial levels, and is supposed to be developed by 2015 and come in to force by 2020. The Durban Platform will make it possible to continue the negotiations (Schreurs, 2012).

COP17 was considered to deliver only superficial outcomes but the perspectives vary depending on which sector one comes from. But the more important outcomes were the Kyoto protocol was kept alive with a road map being agreed on and partially defined as to the way forward; the principle of the Green Climate Fund was accepted with the majority of countries giving their pledges as well as the agreement for some financial instruments. The debate on development vs. adaptation was aired on many occasions with sentiment moving towards strong support for adaptation with the rationale being that in most developing countries, development and adaptation were synonymous and that good development was adaptation (Scholes, 2012).

However, the divergence of views and opinions among parties in the Durban Conference is still large. According to Hu and Monroy (2012) one of the bones of contention is whether the emerging developing countries, like China, should make commitments and legally bind themselves to the GHG reduction target in near future. As the largest GHG emitting country, China and its energy and climate policies will play an important role in global climate change and will also significantly influence the other countries' policies and the global climate negotiation (Hu and Monroy, 2012).

A generous interpretation of what was achieved in Durban is that all countries agreed to be bound by the same legal treaty, or rather agreed outcome with legal force, to be concluded by 2015 and going into effect by the end of the decade. But a less generous interpretation, perhaps closer to the truth, is that the agreement reached at Durban is nothing more than an agreement to work towards an agreement by 2015.

2.4.3 COP18 and COP19: Tug-of-war in Doha and Warsaw

The next meeting was held in Doha, Qatar in December 2012. Fragmentation is a suitable describtion of this policy action as countries follow their own policy agendas (Schwanitz et al., 2015). Despite the divergence of views and interests on a number of key issues, Parties were able to make progress at this "implementation COP", where the key outcomes focused largely on the negotiation process rather than on any substantive issues. The COP18 reached an agreement to extend the life of the Kyoto Protocol. Parties can now focus their efforts under the Durban Platform track of negotiations to reach a new, post-2020 agreement that includes commitments by all major emitters.

The next conference was held in Warsaw, Poland in November 2013. It concluded to be a success, both in terms of outcomes and the organization. All of the Presidency's negotiation objectives have been successfully achieved and additionally strengthened by respect to the transparency and inclusiveness of negotiation process.

The compromise that was achieved during the conference set the direction on the way to the new global agreement to be concluded on COP21 in Paris in 2015, which will be further worked on during COP20 in Lima in 2014. The negotiators agreed the "Warsaw Action Agenda" setting up a path and specific timetable for the development of the 2015 Agreement. All Parties to the UNFCCC decided to initiate or intensify for their intended national contributions for the new global climate regime (United Nations Framework for Convention on Climate Change, 2014).

2.4.4 COP20: A pathway to Paris

The conference was held in Lima, Peru in December 2014. There were no great expectations for the meeting and even if the outcome was weaker than hoped for, it is still better than nothing. The main aim for the COP20 was the foundation established for the next major international climate agreement, which will be finalized and signed in Paris in 2015.

After difficult negotiations, delegates laid the groundwork for a upcoming successful international climate agreement. The meeting concluded with an agreement among 195 countries, the "Lima Accord", which represents both a classic compromise between the rich and poor countries, and a significant breakthrough after twenty years of difficult climate negotiations. They agreed on what information countries must share as they prepare their national climate action plans beyond 2020.

By establishing a new structure in which all countries will state their contributions to emission mitigation by March 2015, this latest climate accord is important as it moves the process in a productive direction in which all nations will contribute to the reduction of GHGs. The objective of the COP21 is to achieve a binding and universal agreement on climate, for the first time in over 20 years of UN negotiations. Figure 5 summarizes past steps in the discussion on commitments.

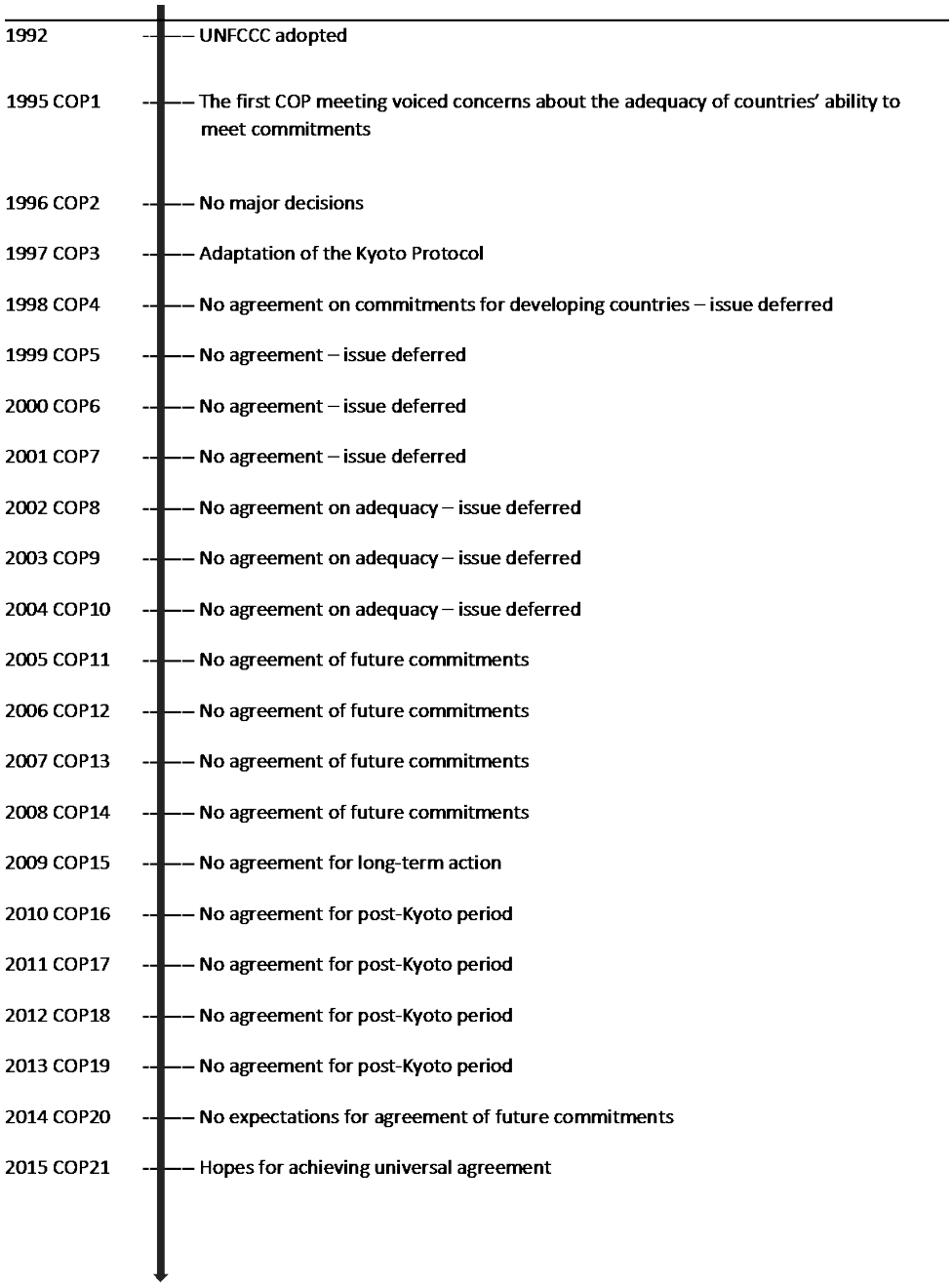

Figure 5. Overview of the negotiating history on commitments

2.4.5 Never-ending meetings?

As stated earlier, a formidable challenge is to decide what will happen in the extended Kyoto period after 2020. Currently, the divergence of views opinions among nations and parties is still largely shown in the international conferences, and the negotiations process about the second commitment period of the Kyoto protocol is still not successful. However, the fact is that developing countries have an increasing pressure to adopt some kind of target. This new agreement needs to be developed in a way that it avoid causing economic misfortune but in a same time allow developing countries to rise out of poverty, while promising sharp, long-term GHG emission reductions. Stated already in 2005 by Halsnæs and Olhoff, a key issue is what kind of potential future targets might be set for developing countries, and how these would be decided.

Industrialized countries are on one hand responsible for most of the problem and should take the first step in reducing emissions. On the other hand, their efforts can only be effective, if also developing countries' emissions do not grow indefinitely. Developing countries need to "get it right in the first place", meaning that these countries do not first become large polluters and then reduce emissions (Höhne, 2005).

The Kyoto Protocol could provide a basis for further action on climate change. It is a flexible and can accommodate new ideas during its review. But considering possible future emission paths, the current commitments in the UNFCCC and the Kyoto Protocol will not be sufficient to reach ambitious long-term targets, such as e.g. stabilization of CO_2 concentration at 450 ppm. According to Barrett and Stavins (2003), the Kyoto Protocol's architecture has been criticized on a variety of grounds, including: It imposes high costs and substantial burdens on some industrialized countries; it does not impose emission commitments on developing countries; it provides ineffective incentives for participation; and it generates modest short-term climate benefits while failing to provide a long-term solution. The Kyoto Protocol is only a first step towards the ultimate objective of the Convention. Eventually participation of all major countries will be required. The question still remains; when and how (Barrett and Stavins, 2003).

As the official negotiations under the UNFCCC on the period after post-Kyoto are in the agenda now, ideas have been exchanged for some time in a number of informal discussion processes and dialogues. These informal discussions are supported by a wealth of scientific and public literature on options on the further development on the international climate change regime (Höhne, 2005; Tol, 2013).

It is not an easy task to find a model, which will satisfy all parties. Instead, there is a regime complex (Keohane and Victor, 2010). Different approaches (Claussen and McNeilly, 1998; Berk and den Elzen, 2001; den Elzen, 2002; Metz et al., 2002; Bodansky, 2004; Höhne et al., 2004; Torvanger and Godal, 2004; den Elzen

et al., 2005; Wei et al., 2013) to assign commitments with respect to climate mitigation to different countries have been proposed (Kuntsi-Reunanen and Luukkanen, 2007, hereafter referred to as Article III). Unfortunately, none of them were widely accepted in the climate negotiations and neither was put up as a post-Kyoto mitigation proposal.

2.5 Precondition for differentiation of commitments

Article 3.1 of the UNFCCC requires that the mitigation effort should be shared between parties "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities". In order to reach a global solution, the equity issue has to be solved. Each country has to have the impression that it is treated equitably relative to the others in order for it to participate (United Nations Framework Convention on Climate Change, 1992b).

A major challenge in global climate change negotiations is to find a scheme for differentiation of GHG mitigation commitments among countries that can be accepted as fair by all or at least most governments (Winkler, 2002). For this purpose, it is useful to attempt to identify a set a fairness principles that are widely accepted by governments and therefore may serve as a basis for distributing GHG mitigating commitments among countries.

The concerns of equity and efficiency are important in the evaluation of the possible burden sharing models, which determine emission commitments for different countries.

2.5.1 Equity

There is no common accepted definition of equity. Equity principles refer to more general notions or concepts of distributive justice or fairness. Many different categorisations of these principles can be found in the literature (Berk and den Elzen, 2001; Jansen et al., 2001; Sijm et al., 2001; Ringius et al., 2002; den Elzen and Lucas 2005; Mattoo and Subramanian 2012). Rose et al. (1998) distinguish three types of alternative equity criteria for global warming regimes:

1) *allocation based criteria*, defining equitable differentiation of commitments in terms of principles for the distribution of emission allowances or the allocation of emission burdens;
2) *outcome based criteria*, defining equitable differentiation of commitments in terms of outcome, in particular, the distribution of economic effects, and

3) *process based criteria*, defining equitable differentiation of commitments in terms of the process for arriving at a distribution of emission burdens.

The distinction is important, as almost all approaches are allocation-based. A disadvantage of outcome-based approaches is that they are dependent on complex economic models, the outcomes of which are usually not transparent to policy-makers. On the other hand, the perceived costs and economic impacts of options for differentiation of future commitments will have an important impact on the evaluation of policy options. Process-based criteria are generally less suitable for ex ante evaluation because their outcomes are less predictable.

Ringius et al. (2002) use another typology based on the type of equity principles relevant in the context of climate change:

1) *egalitarian*, all humans beings have equal rights to use the atmosphere;
2) *sovereignty*, current emissions constitute a status quo right now;
3) *horizontal*, actors under similar economic conditions have similar emission reduction commitments;
4) *vertical*, the greater the capacity to act or ability to pay the greater the economic burden;
5) *polluter pays*, the greater the contribution to the problem the greater the burden.

They note that in practice proposals for differentiation of commitments often use formulas that relate to different equity principles and multiple criteria relating to both economic and environmental dimensions of climate change regimes. In their view, the principle of horizontal equity was dominant during the negotiations of Kyoto protocol. In both UNFCCC and Kyoto protocol, the relations between the developed and developing countries are much more described in terms that refer to vertical equity and the polluter-pays principle.

Later, focusing on the most relevant elements for a widely accepted approach to burden differentiation in future international climate negotiations, Ringius et al. (2002) simplify their typology of "principles for distributive fairness" down to three key principles:

1) *responsibility*, costs should be distributed in proportion to a party's share of responsibility for causing the problem;
2) *capacity*, costs should b distributed in proportion to ability to pay;
3) *need*, all individuals have equal rights to pollution permits, with a minimum to ensure basic human rights, including a decent standard of living.

2.5.2 Efficiency

In addition to equity, to achieve economic efficiency the emissions should be mitigated where least costly. Solutions to the conflict between equity and efficiency include cap-and-trade systems or harmonized emission taxes. Under perfect markets without uncertainty, the approaches should produce the same outcome. The equity issue can then be dealt with either the allocation of tradable emission allowances or the redirection of tax revenues.

In a perfect market setting the allocation of emission allowances is merely a financial compensation. The parties are free to trade allowances and their actions are guided solely by the market price of allowances, not by how much party initially owns allowances. Therefore in principle the mitigation costs of the parties could be adjusted through the allocation without affecting the actual mitigation measures (Ekholm et al., 2010).

The level to which the global emissions should be reduced is obviously debatable. However, under certain conditions, the optimal level of abatement for different countries does not depend on the allocation of allowances. Therefore the overall abatement level and equity issues can be separated and analysed on their own.

Given an overall emissions limit, effort sharing deals with the distribution of limited emission allocations to the parties. The effort sharing process and tools used should be reliable, understandable and transparent in order to build confidence in the process. The resulting allocations, however, can, and moreover should, be analysed with more sophisticated if less transparent models (Ekholm et al., 2010).

In this thesis the discussion of all approaches is based on the following common assessment criteria. These criteria arise from the intention to strive for an optimal approach that is likely to be agreed successfully. The criteria also take into account earlier assessments (Berk and den Elzen, 2001; Philibert and Pershing, 2001). The following four criteria have been considered to be the most critical in evaluating future emission reduction options (Höhne et al., 2003).

Box 3. Assessment complied from Höhne et al., 2003

1) Environmental criteria
   - Environmental effectiveness: The optimal approach must ensure that stringent global emission targets are reached to safeguard the fulfilment of the ultimate objective of the Convention. Accordingly, it should include GHGs from all important sources and sectors and avoid leakage (the transfer of emissions to other countries instead of the reduction). It should promote for ancillary benefits of the emission reductions and should provide certainty of the emission levels on the global level as well as for participating parties.
   - Encouragement of early action: Since major reductions of global GHGs are needed to reach the ultimate objective of the Convention, it is necessary that all parties avoid unnecessary emissions. The optimal approach would encourage countries that do not yet have binging commitments to keep emissions as low as possible.
2) Political criteria
   - Equity principles: Three equity principles should be covered by the optimal approach to a certain extent in order to be successful:
     - It should allow that countries to develop economically to satisfy their basic human needs and that this development should be geared towards sustainability (principle of need)
     - It should require those countries to take on a burden that have the economic ability to pay and to undertake action (principle of capability)
     - It should require those countries to take on a higher burden in reducing emissions that pollute more (principle of responsibility
   - Agreement with the fundamental positions of major constituencies: Since the international negotiation process is based on decisions by consensus, the optimal approach would have to be acceptable for all constituencies. This means that the approach is perceived as not posing unproportional burden to some countries, while favouring others. It should also rely not on only one group's position but be a compromise of all proposed approaches. Assessment of this criterion is based on the current positions.
3) Economic criteria
   - Accounting for structural differences between countries: Since starting positions of countries are very diverse, the optimal approach would take these differences explicitly into account.
   - Minimizing adverse economic effects: The optimal approach would require a distribution of reductions so that the global costs are minimised. The optimal approach would also give participating sovereign nations sufficient flexibility to reach their commitments, tailored to their national needs and priorities. Such an approach would avoid being prescriptive in the action but leaving room for the implementation of the target, e.g. reducing emissions in different sectors, or reducing emissions of different gases, etc. In addition, the optimal approach would ensure that participating countries have certainty on the inferred costs of taking on commitments.
4) Technical criteria
   - Compatibility with the structure of the UNFCCC and the Kyoto protocol: The optimal approach would be compatible with the existing international structures of the Convention and the Kyoto protocol as to benefit from the international negotiations that have taken place to date. Institutions and structures implemented for the use of the Kyoto mechanisms could be utilized.
   - Moderate political and technical requirements for the negotiation process: Since the international negotiation process is based on decisions by consensus, the optimal approach should be simple and require a low number of separate decisions by international bodies. In addition, all necessary data and tools should be available and verifiable. If data is not available, there should be the opportunity that it can be collected and verified in the future. If the approach requires a calculation method, these should also be available and verifiable. Finally, the optimal approach would allow that the implementation of the targets can be monitored and verified.

As noted in Höhne et al. (2003), potential conflicts between these criteria exist. Very simple approach would be relatively easy to negotiate but cannot explicitly address the national circumstances of individual countries. Complex formulas for future commitments, which can accommodate particular national circumstances, may be difficult to negotiate. Consequently, the optimal approach may not be available. It will always be a compromise that satisfies the above criteria only partly (Höhne et al., 2003).

2.5.3 Assessment for commitments

Article III provides the description and assessment of the approaches with respect to the above criteria. Moreover, the approaches have been selected for further analysis which represent efforts well and are technically quite feasible. There are more than 50 proposals either published or publicly presented in recent years. However, this thesis concentrates only on the most original and interesting methods and models used in burden sharing proposals. These selected approaches are regularly referred in field literatures, and they all try to use objectively defined criteria for differentiation and try to factor in equity (Article III). These are as follows:

i) Brazilian proposal
ii) Triptych approach
iii) Multi-sector convergence approach
iv) Contraction and convergence approach
v) Multistage approach
vi) WITCH-model

Brazil has proposed a model, which is based on historic emissions. The proposal suggest that the Annex I countries would be required to reduce their emissions by 30% by the year 2020. The burden is to be shared on the basis of the warming each country has with their cumulative emissions so far. Therefore, countries with a longer history in industrialization would be required to make larger reductions whereas those that have industrialized relatively late would have to reduce less. Emissions quotas would be tradable and if a country exceeded its target, it would have to pay a punitive fine into a clean development fund (United Nations Framework Convention on Climate Change, 1997b).

As an alternative development, there could be a shift in focus from the level of the nation state towards the level of sectoral policies, which could be applied to a limited set of parties to the FCCC, but also be fully international in nature, such as in the case of industries dominated by a limited number of key multinational

companies. Such a shift would fit in with a more bottom-up approach for defining commitments. An example of this kind of bottom-up model is the global application of the *triptych approach*. This approach was successfully used in the European Union before the Kyoto Protocol, to help defining an internal burden sharing agreement. This approach could be a useful and an attractive approach to define developing countries future burden sharing.

The *multi-sector convergence approach* by CICERO and ENC is based on a comprehensive accounting framework of GHG emissions by different sectors within national economy. It takes as point of departure that, in principle, the amount of per capita emission assignments will have to ultimately converge to the same level for all countries and accommodates for the possibility that additional allowances may be granted to countries facing specific circumstances.

The *contraction and convergence (C&C) approach* would mean a major shift away from the present Protocol approach towards defining commitments for all Parties and their evolution over the long-term. This approach can be seen as the most comprehensive application of per capita entitlements. The C&C determine a concentration target and then invents a global carbon budget accordingly (Global Commons Institute, 1998b). Emissions have to be reduced gradually in order to stay within the budget. Eventually, emissions will reach a much lower than current level. In the approach, the convergence means that countries will reach equal emission levels per capita by a given year. Developed countries whose emissions per capita are clearly above the sustainable level would reduce their emissions while developing countries under that level would be allowed to increase their emissions. After the convergence has been taken place, the relative shares of different countries will remain static, but the contraction will continue. Thus, emission trading is a central feature of the model (Global Commons Institute, 1998b).

The *multistage approach* is basically a system for gradual extension of the group of countries taking on qualified emission limitations and reduction objectives and deepening of their commitments over time. It consists of a system to divide countries into groups with different levels of responsibility or types of commitments (stages) which results in a system that divides regions into groups with different levels of commitments (stages) (den Elzen and Lucas, 2003).

A different way of looking at international climate policies consistent with the long term goal of stabilizing atmospheric concentrations was made by Bosetti et al. (2009b). They use the integrated assessment model *WITCH* (Bosetti and Buchner, 2009; Bosetti et al., 2009a; Bosetti et al., 2009b) to investigate the economic and investment implications of climate policy, assuming either immediate or fragmented participation.

3 MATERIAL AND METHODS

3.1 Data collection procedures

In 2015, the latest data available of CO_2 emissions from fuel combustion, GDP and population are from 2013 (IEA, 2013a; IEA, 2013b). However, this thesis concentrates on the last decade's data. The data used for the analysis were derived from IEA statistics (IEA, 1997; IEA, 2000; IEA, 2002; IEA, 2003a; IEA, 2003b; IEA, 2003c). The GDP data have been complied for individual countries at market prices in local currency and annual rates. The data have been scaled up or down to the price levels of 1995 and then converted to US dollars using the yearly average 1995 purchasing power parities. All the presented data are macroeconomic, country level data. The sectoral approach contained total CO_2 emissions from fuel combustion as calculated using the IPCC sectoral approach. Emissions calculated using this approach included emissions only when the fuel was actually combusted. The reason to use only CO_2 emissions in the calculations was the availability and reliability of the long term time series. The main source of the 1971 to 2001 population data was the OECD (IEA, 2003a). The population growth rates with a medium variant from 2002 to 2050 were from the United Nations (United Nations, 2003; Article IV).

Future CO_2 emissions for different countries were estimates made by the Global Commons Institute (Global Commons Institute, 2003). The estimates indicated the rate of change required to reach the C&C target of 1.8 tons of CO_2 per capita by 2040, based on the target concentration level of 450 ppm of CO_2 by 2100 (Global Commons Institute, 1998a). The 'jumps' in the intensities of some countries between 2001 and 2002 were due to slight differences in the data from the IEA and GCI regarding past CO_2 emissions (Article IV).

The required future trends of CO_2 intensities presented in this thesis were calculated by dividing the future emissions, produced with the C&C model, by the estimated future GDP. Future economic growth rates were scenarios on the basis of a joint study of the different regions in the world by the International Institute for Applied System Analysis (IIASA) and the World Energy Council (WEC) (Nakićenović et al. 1998).

As most developing countries are currently not in a position to make absolute emissions reductions, the most immediate and realistic challenge is lowering the CO_2 intensity of the economies. Thus, rather than measuring the absolute amount of a country's emissions, the CO_2 intensity indicator provides a more realistic and practical framework for participation by expressing the emissions that an economy generates per unit of output. This is an effective way to benchmark national progress in climate change mitigation (Article II).

Carbon dioxide emission intensity of an economy describes how many tons of CO_2 are emitted for each dollar of economic output of the nation, measured as GDP (CO_2/GDP). The changes in emission intensity are caused by technological changes in energy and production technology (e.g. changes in energy efficiency), changes in the shares of fuels used for energy (e.g. a shift from coal to gas) and changes in the economic production structure (e.g. a shift towards a service economy) (Article II). Decreasing energy intensity indicates that less CO_2 emissions are produced for the same economic output. The required change in emission intensity to achieve the emission target indicates the required structural changes in the production system and, hence, the level of difficulty to be overcome to achieve the target (Article IV). In most industrialised countries, the emission intensity has been declining.

In general, as Sun already pointed out in 2003, the trend of energy intensity has risen in most developing countries due to increased industrialization, urbanization, a greater demand for the development of transport, infrastructure and the modernization of life styles (Sun, 2003; Article I).

3.2 Methodological approaches

Database development forms an integral part of the research. Without a comprehensive database it is not possible to carry out relevant quantitative research (Bernauer and Böhmelt, 2013; Munang et al., 2013). Database development consists of energy and climate related data collection from existing data sources, checking of the reliability and consistency of the data, producing new data and indicators from the source data by applying statistical and computational operations and organizing as well as managing the data.

The analysis of socio-economic and historical context of energy and climate policy in developing countries forms an essential part of the research. This is important for the relevance and applicability of the results. The socio-economic context forms the background for more detailed sectoral case studies.

The case studies of the dynamic CO_2 and energy efficiencies and the related measures of sustainability and welfare dynamics form the empirical part of the research. The empirical research will be extended to a comparative study of different groups of countries and for selected individual countries using the methodology developed in this thesis. The different groups of countries consist of South American countries and Southern Asian countries in comparison with the USA, Japan, France, the United Kingdom and Germany. More detailed case studies at a sectoral level will be carried out for selected developing countries, namely India, Thailand, Brazil and Venezuela.

In the policy studies, the result of the empirical analysis will be linked to the issues of the national and international climate policy. In this respect, the results will be of great importance for the discussions of the burden sharing for the second and consequent Kyoto commitment periods. Comparative information of the position of developing countries is important for the climate policy negotiations. The linkage to the Kyoto mechanisms, in this case especially to the Clean Development Mechanism (CDM), will form another policy relevant topic for the analysis of the study. CDM allows for emissions reduction projects to be implemented in developing countries that generate emission credits. Such schemes supplement emissions trading by allowing access to lower cost abatement opportunities. The empirical efficiency analysis can produce important background information for the planning and decision making of the future CDM investments and their geographical distribution.

3.2.1 Contraction and convergence (C&C) approach

In the methodological development approach of this work, the idea is to develop further the so-called contraction and convergence model (C&C) (Luukkanen et al., 2005; Article IV) presented originally by Global Commons Institute in the late 1990's. The thesis examines the post-Kyoto burden sharing questions for developing and industrial countries using the C&C model, which is one of the many approaches that have been proposed to allocate commitments regarding future greenhouse gas emissions mitigation. The approach is based on equal per capita emission rights and concedes individuals' equal rights to pollute permits. The approach has a long-term decacal perspective with respect to the distribution of the rights and duties and their evolution over time. The problem with the developing country participation is that many developing economies are in the industrializing phase with increasing emission intensities. From this point of view, the C&C model may not look very attractive to them although the possibilities for selling extra emission rights at low level of emissions per capita may turn out to be attractive, at least in the short term. In the study, the historical rates of CO_2 emission intensity for different countries will be analyzed and compared with the future intensity rates that are required to achieve the C&C target of 1.8 tons of CO_2 per capita in the year 2040 (Article IV).

3.2.2 Environmental stress approach

In addition, environmental stress approach as measured by CO_2 emission intensity has been also used (Article I). The approach provides a new tool for developing

indicators, which capture important aspects of sustainable development. The approach relates the environmental stress to basic indicators of economic, technological and social development and constructs new explanatory factors for the sustainability analysis of systems. This approach conceptualizes and operationalizes some of the key aspects of sustainable development such as sustainable economic growth, sustainable technological development, dematerialisation, immaterialisation and welfare. Therefore, environmental stress approach provides new perspectives to global and country level development studies.

The CO_2 emissions of an economy are defined with the aid of the CO_2 intensity of production and the production volume as GDP. The CO_2 intensity of the economy is defined as the CO_2 emissions divided by the Gross Domestic Product, GDP:

$$CO_2 \text{ int} = \frac{CO_2}{GDP} \quad (1)$$

The future development of CO_2 emissions in a country can be defined by the estimated CO_2 intensity of the future and the estimated GDP growth or decline. The changes in CO_2 intensity depend on several factors, but the general development path of an industrialising nation has been increasing intensity in the industrialization phase and decreasing intensity when the economy more towards a service sector dominated system.

The level of the CO_2 intensity of the economy depends strongly on the production structure and the energy sources that are used. The transport sector can have an important effect on the level of the CO_2 intensity in countries, especially those with a high share of private car based passenger traffic and truck dominated freight transport (Luukkanen et al., 2005).

In the study, the historical rates of CO_2 emission intensity for different countries are analysed and compared with the future intensity rates that are required to achieve the C&C target of 1.8 tons of CO_2 per capita in the year 2040 (Article IV).

Combining the environmental stress approach and C&C model forms an important and demanding research task. Thus, they both are suitable for explaining the reality of climate policy.

4 RESULTS

4.1 Southern Asia: Decoupling production and emissions

Article I analyzed the environmental impact of energy use in Bangladesh, India, Pakistan and Thailand from 1973 to 2000 based on the International Energy Agency's database. According to the generally accepted view, the demand for fossil fuel in the developing countries has rapidly increased. Thus, it has been assumed that the trend of energy intensity has risen in most developing countries due to increased industrialization, urbanization, and a greater demand for the development of transport, infrastructure and the modernization of life styles. Furthermore, because of CO_2 emissions related to energy use resulting from fuel combustion, the increase of energy intensity is assumed to have brought about an increase of CO_2 emission intensity.

The findings in Article I differ from some previous conclusions. The study indicated that CO_2 emission intensity has declined in these four countries since the latter period of 1990s. Figure 6 shows that CO_2 emission intensity has declined since 1992 for India. See Article I (figures 5, 7 and 8) for similar declining since 1995 for Bangladesh, 1999 for Pakistan and 1998 for Thailand.

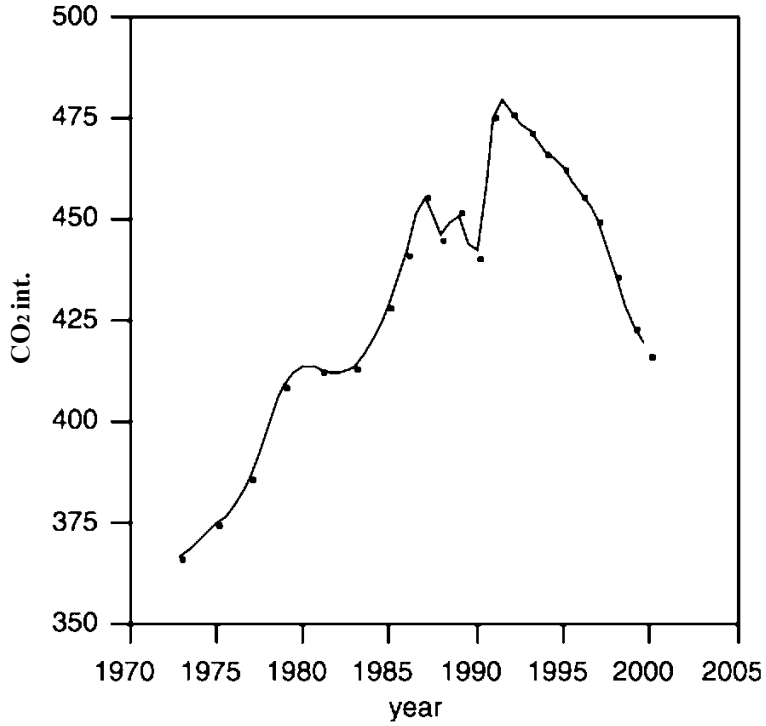

Figure 6. CO_2 emissions intensity in India from 1973 to 2000 using IEA (2002) database. (Unit: CO_2 emission intensity: kg of CO_2 emissions/1000 US dollars at 1995 prices and PPPs.) *Source: Article I.*

In other words, the above four countries are in the process of dematerialization with regard to energy use and are thus heading forward decreasing environmental stress. This implies that energy consumption in the above Southern Asian developing countries has followed a pattern of energy use similar to that of the developed countries. In energy economics, the decline of energy intensity is attributed to the outcome of social and economic development and progress. However, from the viewpoint of social development, the economy and technology, these Southern Asian developing countries do not fulfil the requirements of industrial condition. According to United Nations Development Programme (1998) classification of countries, Bangladesh, India and Pakistan belong to low income countries, whilst Thailand belongs to lower middle income countries (United Nations Development Programme, 1998).

The changes in the structure of CO_2 emissions and the increase in the utilization of combustible renewables and waste imply that a change in the fuel mix of those countries has lowered their CO_2 emission intensity. It can be concluded that the environmental impact of energy use in Bangladesh, India, Pakistan and Thailand is being addressed in some form.

4.2 Latin America: Energy-related emissions

The purpose of the second article was to evaluate the macroeconomic performances of the selected Latin American countries' energy systems and therefore to contribute to the energy and climate policy discussion and the potential post-Kyoto commitment of these countries. The comparative information regarding the development of CO_2 intensity effects in a country should help inform national energy policy makers of the relative weaknesses and possible areas of strategic emphasis in their planning processes. This kind of research is needed as similarly to many developing countries, Latin American energy markets are also growing.

In relation to the CO_2 emissions, it is important to compare the per capita emissions. In Figure 7, the CO_2 emissions from fossil-fuel combust in the different Latin American countries from 1971 to 2001 are compared.

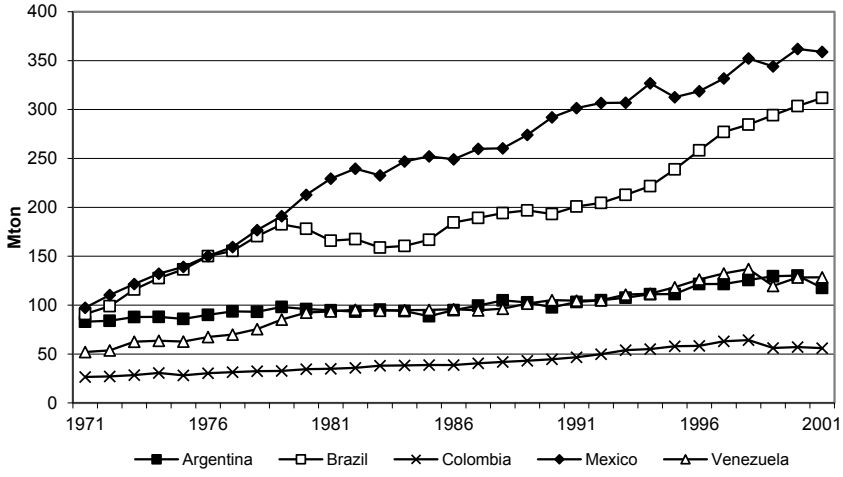

Figure 7. CO_2 emissions in the Latin American countries from 1971 to 2001. *Source: Article II.*

In Figure 7, an increasing trend in the CO_2 emissions from the 1970s can be seen in all of the selected countries. The growth was most notable in Mexico and Brazil in contrast to Argentina and Colombia where the growth was quite moderate with a slight decrease in the last few years.

Figure 8, CO_2 emissions per capita in the different Latin American countries from 1971 to 2001 are compared.

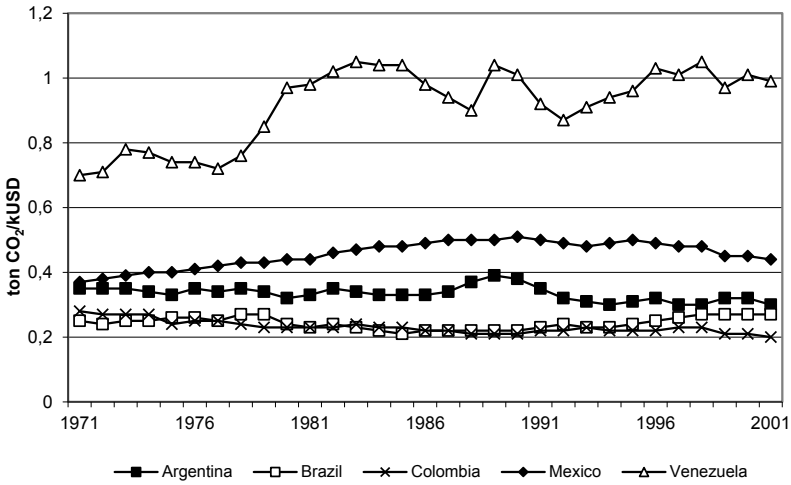

Figure 8. Changes in the CO_2 emissions per capita of the economies of the Latin American countries from 1971 to 2001. *Source: Article II.*

Figure 8 illustrates that emissions per capita have increased most notably in Mexico where population growth has been the main factor in increasing emissions. From the 1970s until the end of 1990s, a slight increase can be noted in Brazil and Colombia, whereas in Argentina and Venezuela clear trend cannot be seen as the emissions have been fluctuated the whole research period.

Results from the selected five Latin American countries reveal quite similar changes in CO_2 intensities. The article showed that the CO_2 emission intensities fluctuated the whole research period without a clear trend in all those Latin American countries, with the exception of Mexico where the CO_2 emission intensity increased in the 1970s and 1980s and then turned to decrease. However, the energy use varied somewhat indicating differences between the energy utilization in the analysed countries. No significant changes were found in any of these countries' energy utilization during the study period although the energy markets were growing quite rapidly.

4.3 Acceptable burden sharing options

Article III explored the issue of burden sharing in developing countries by assessing different kinds of future target options for these countries. The study introduced some of the most original and interesting methods and models used in burden sharing proposals. Each of these approaches was evaluated according to criteria of environmental effectiveness, cost-effectiveness and equity.

The article analysed alternative methods of how the burden should be shared among nations after the Kyoto Protocol first commitment period. Brazilian proposal, the triptych approach, the multi-sector convergence, the C&C approach and the multistage approach try to use objectively defined criteria for differentiation and try to factor in equity. It is possible to construct models, which try to take into account several aspects related to both equity and efficiency. However, the models may easily become very complex, if all the different natural circumstances and aspects are tried to be covered. The differences in natural resources vary so much between countries that it would require hundreds of compensating factors to be taken into account and still the results could be questionable. In addition, the complexity of the model will certainly hinder the possibilities for political acceptance because the various exceptions may easily lead to bargaining and disputes of the results.

The study concluded that no single criteria can lead to acceptable solution from every perspective. It is difficult achieve equitable efficiency, but still worth of trying to find solution. The paper pointed out that different kind of burden sharing models can be seen as alternative models of global responsibility.

4.4 Contraction and convergence – a potential remedy?

Article IV analysed how allocation schemes determined by the contraction and convergence approach might affect certain OECD and non-OECD countries. The article sought to establish what changes are required in countries' current emission intensities to achieve the contraction and convergence targets.

Results for eleven countries selected for the analysis (the United States, the United Kingdom, Germany, France, Japan, China, Venezuela, Thailand, Brazil, India and Indonesia) revealed that trends observed in the past few decades in most industrialized countries will indeed lead to the desired target under the contraction and convergence scheme. Generally, industrialized countries have to follow their current downward trend (Figure 9), which can be achieved by continuous structural change in the production system. Economic growth has to continue its shift towards lighter sectors of the economy such as services, plus information and communications technology (ICT).

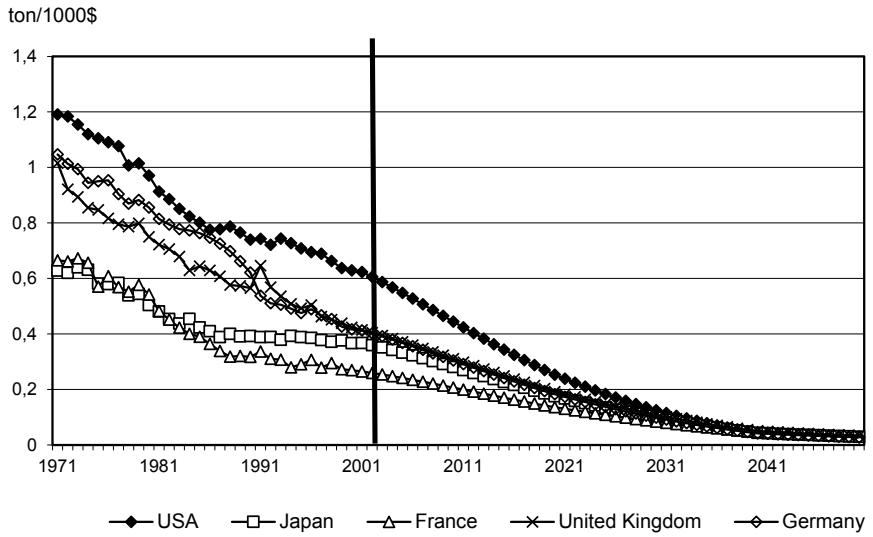

Figure 9. Changes in the CO_2 intensity of the economies (CO_2 emissions/GDP) in the USA, Japan, France, the United Kingdom and Germany from 1970–2001 (Source: IEA 2003a) and the required development from 2002–2050 to reach the C&C target. The CO_2 emissions per GDP allocated to industrialised countries, 1970–2050, were calculated on the basis of C&C model and WEC and IIASA estimates of economic growth. *Source: Article IV*.

For developing countries, the situation is different. Some developing countries, such as India and Indonesia (Figure 10), can still increase their emission intensities until 2015. After this, their intensities would have to start decreasing. However, since the model requires not only contraction, but also convergence of per capita emissions between countries, countries such as Venezuela and Thailand (Figure 11), with their relatively high per capita emissions, are required to start reducing their emission intensities immediately.

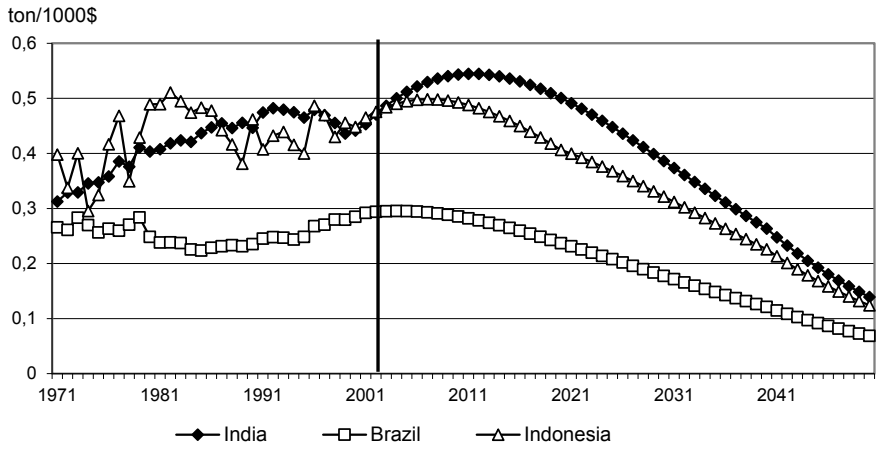

Figure 10. CO_2 intensity of production (CO_2 emissions/GDP) in India, Brazil and Indonesia 1971–2050 according to C&C model. *Source: Article IV*.

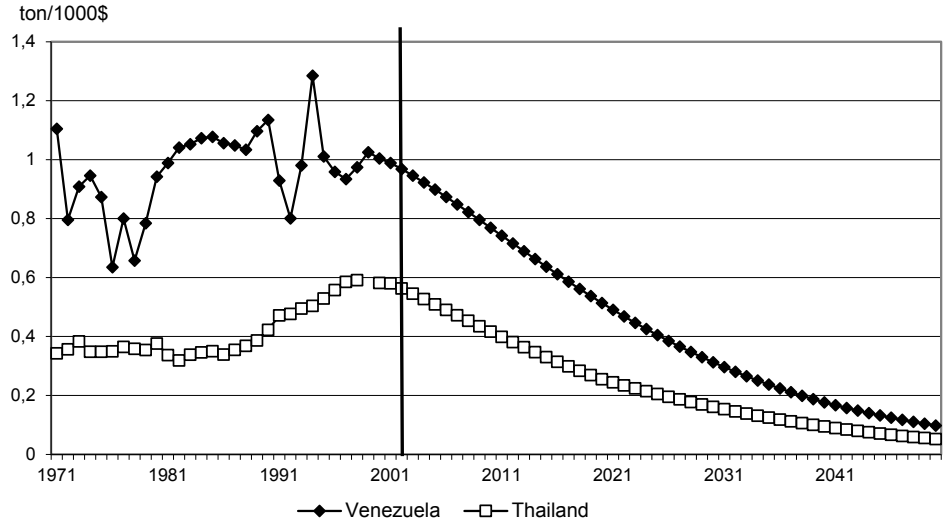

Figure 11. CO_2 intensity of production (CO_2 emissions/GDP) in Venezuela and Thailand 1971–2050 according to C&C model. *Source: Article IV*.

5 DISCUSSION

5.1 Critical analysis of the burden sharing proposals

5.1.1 Brazilian proposal

Even in its revised form, the Brazilian proposal contains methodological shortages. Is not particularly suitable for global implementation as the computer simulation with a participation threshold is only for non-Annex I countries. In addition, the proposal downplays the significance of current emission levels. Thus, penalising the present generations for what their predecessors did in the early 19th Century goes too far in history (United Nations Framework Convention on Climate Change, 1997b; den Elzen et al., 1999; Luukkanen and Kuntsi, 2003).

The proposal also takes no account of the relative impact of other GHGs and the various climate system feedback mechanisms on global warming. Since scientific findings will inevitably have to be modified over time, this presents a problem for the system, which would be very difficult to revise in the light of new science.

According to Evans (2002), the proposed reduction target for developed countries of 30% by 2020 also seems arbitrary, with no obvious link to scientific assessment of the reductions that need to be made in order to avoid further climate change, and it is unclear what would happen after this date.

Above all, question mark hangs over the proposal's environmental effectiveness because it has no quantified and binding limitations for developing countries, and hence no fully global framework for controlling atmospheric concentrations.

Without that, the Brazilian proposal is environmentally incomplete: under a system like that, it would be impossible to predict with any certainty the net global emissions of each year of the ultimate endpoint in terms of a atmospheric concentrations of CO_2 and other GHGs (Evans, 2002).

In one sense, the proposal is an attractive model of equity that seems to epitomise the polluter pay principle. It also appears address some of the dimensions of the ecological debt argument, although not to the extent of actually compensating developing countries for damages suffered (Evans, 2002).

According to den Elzen and Lucas (2005) the Brazilian Proposal is unattractive to OECD-Europe due to its relatively large historical contribution to temperature increase, but also to Latin America. Southern Africa, South Asia and Northern Africa benefit from the no-binding commitments before participating in the emission reductions, which for them makes Brazilian Proposal attractive (den Elzen and Lucas, 2005).

5.1.2 Triptych approach

Even if the triptych approach has several strengths (Phylipsen et al., 1998), weaknesses also exist. The approach is able to consider and accommodate national circumstances. It explicitly allows for incorporating economic growth and improving efficiency in developing countries. It has been successfully applied on EU level as a basis for negotiating targets. But the approach itself is rather complex and requires many separate decisions, requires much data on a sectoral level and may therefore be perceived as not transparent. In addition, projections of production growth rates for heavy industry and electricity are required. An agreement on all these issues on a global level may be difficult (Höhne et al., 2004).

In sharing emission allowances, there is a general conflict of being simple and not able to accommodate many national circumstances and concerns (e.g. converging per capita emissions) on the one hand and being sophisticated and able to accommodate them on the other hand. The triptych approach clearly belongs to the more sophisticated methods. According to Höhne et al. (2004) the experience with sharing the EU Kyoto target among member states EU has shown, that also complex solutions can be the basis for an agreement. Hence the approach can also in the future provide the basis for the sharing of emission allowances between countries within a group (Höhne et al., 2004).

As stated in Höhne et al. (2003) early action in the domestic sectors is rewarded, since emissions of these sectors will eventually convergence and less reduction will be necessary to reach the per capita convergence level. For the power sector and the industrial sector, assigning targets based on future emission levels may be an incentive to increase emissions until then to be granted a higher targets once participating (Höhne et al., 2003).

As the principle of allowing economic growth is addressed in this approach, countries are allowed to grow in terms of electricity production and industrial production, but have to improve their production efficiency. The targets are set in a way that they can be reached with increasing implementation of energy efficient and renewable energy technology without prescribing reduction measures. The principle of capability is not explicitly addressed. The principle of responsibility is addressed through the fact those countries that have higher emission levels in the domestic sector must reduce emissions more. The historic responsibility of countries is not explicitly taken into account (Höhne et al., 2003).

Structural differences are taken into account explicitly at a sector level. The differences in the standard of living, in future population growth, in fuel mix for power generation, in the economic structure and energy efficiencies and projected future changes in economic structure are taken into account (Groenenberg et al., 2001). A major downside of the approach is that the choice of sectors is based on

the emissions structure of industrialised countries. For developing countries emissions of other sectors and gases may be more important (Höhne et al., 2003).

The major disadvantage of the triptych approach is that it is complex and the data requirements are comparatively high. The approach requires a set of scenarios, including the expected growth rates of production in the various sectors. Triptych may have fared well in the context of the EU, but global allocations are very different.

The triptych approach is, in general, attractive to the OECD regions with relatively low emission intensities, i.e. OECD-Europe and Japan. The approach is also attractive to the middle-income regions, Latin America, the Middle East and Turkey. The triptych is in particular unattractive for South Africa, South Asia and East Asia due to their relative inefficiency in the power and industrial sector, and their dependency on coal (den Elzen and Lucas, 2005).

5.1.3 Multi-sector convergence approach

The multi-sector convergence approach defines national emission limits based on a global stabilization goal. The principle of allowing economic growth is addressed in this approach, since countries only participate if they have reached a certain graduation level. The principle of capability is not explicitly addressed. The principle of responsibility is addressed through the graduation criteria based on per capita emissions and the fact those countries that have higher emission levels must reduce emissions more. The historic responsibility of countries is not taken into account (Höhne et al., 2003).

According to Höhne et al. (2003) for all countries, per capita emissions of the different sectors have to converge. This neglects however, that some countries have more industrial activity of a certain kind per inhabitant than other countries. For individual countries the sectoral targets may be stringent of loose, depending on the national circumstances and the share of the industrial activity per inhabitant. Therefore, the major downside of the approach is that it uses per capita emissions at a sectoral level for different industrial and agricultural activities, while these activities may not be directly related to population (Höhne et al., 2003)

Since the multistage approach can combine many ideas, it could be a framework for a compromise. But by agreeing on the absolute level of global emission for every 5-year step, stringent global stabilization levels could be reached such as 450–550 ppm CO_2. These stringent paths could, however, only be reached together with early graduation and stringent GHG intensity targets at stage 2, otherwise no emissions are available for the reducing Parties. If the GHG intensity targets for the countries in stage 2 are set lower than the business-as-usual development, hot air could be introduced. Discussion on the threshold for

moving into a next step or the exact emission targets would have to be agreed, but the general concept of several stages seems promising (Höhne et al., 2003).

5.1.4 Contraction and convergence approach

While there are many advantages of the contraction and convergence (C&C) approach (Meyer, 2000; Meyer, 2001), several obstacles prevent the approach from being globally acceptable: C&C does not take national circumstances other than current per capita emissions into account. In particular, it does consider the historical contribution of particular countries to the problem and is therefore likely to meet objections from key developing countries with low emission in the past but relatively high per capita emissions today. They will argue not to be responsible for the problem although they currently have relatively high per capita emissions. Many developed countries will reject C&C because of expected large resource transfers and tropical hot air, as well as political opposition against the global commons and egalitarian concepts underlying the approach (Höhne et al., 2004). There may be excess emission allowances (hot air), but this will not affect the effectiveness nor the efficiency of the regime, only the distribution costs.

An early participation of especially the least developed countries may cause implementation problems with reporting emissions and compliance due to their technical and institutional requirements that are particularly missing in less developed countries at the moment. Involving these countries in international emission trading will be difficult due to lack of reliable emission data, capacity to generate data to meet eligibility requirements, and sufficient capacity for verification and enforcement (Höhne et al. 2004)

Another problem with C&C approach may be that countries that benefit from emission trading under the Kyoto Protocol, such as Russia, may lose their markets once developing countries join the global emission trading regime. But the most difficult problem will be the political acceptance of the per capita emission allowance concept, in particular, by countries with high per capita emission like the USA, Canada and Australia. However, according to Böhringer and Welsch (2004) economic analysis seems to indicate that even for these regions the welfare losses involved (in terms of lifetime consumption) may be limited to a few per cent. This is substantial, but moderate, compared to the overall welfare increase projected in the baseline.

The simplicity of the approach is also the major disadvantage, that it does not account for the structural differences of countries and their ability to decrease their emissions. For stabilization levels of 450 or 550 ppm CO_2, per capita emissions have to decrease below the current world average and many developing countries would have to decrease emissions below their business as usual path. Only a few

least developed countries could sell for a short period of time easily earned emission allowances to developed countries (Höhne et al., 2003).

The C&C is attractive to OECD-Europe and Japan because of its relatively low per capita emissions and the fact that under C&C, all countries contribute. The earlier contribution of the non-Annex I regions makes C&C a relatively less attractive approach for South Asia and East Asia. Since the per capita emissions for East Asia are close to the world average per capita emissions, they do not gain from the C&C, and therefore the C&C approach is not so attractive approach to them.

Böhringer and Welsch (2004) used a dynamic multi-region general equilibrium model of the world economy to assess the economics of a scenario, which entails contraction of global carbon emissions by 25% as compared to 1990 emission levels with convergence towards equal per capita emission rights over the time horizon 2010-2050. The C&C scenario reflects both scientific evidence on the need for stringent future emissions reductions at the global level and broadly accepted equity considerations based on the justice principle of equality of resources.

According to Böhringer and Welsch (2004) it appeared that the C&C merged with the idea of international emissions trading, has potential merits in terms of cost effectiveness and distributive equity, and hence international political feasibility. Emissions trading not only reduce global welfare costs by one half, but also deliver a Pareto improvement when all emission reductions take place domestically. The distribution of the total efficiency gains from permit trading not only improves the economic well-being of all regions as compared to strictly domestic action, but in particular raises economic welfare of major opponents to carbon restrictions from the developing world even beyond non-abatement baseline levels. A decomposition of the general equilibrium effects associated with C&C showed that changes in terms of trade constitute a key determinant of the overall welfare effects (Böhringer and Welsch, 2004).

While C&C has made recurring appearances in international climate negotiations, it is not on the official agenda neither taken into serious consideration. It is questionable whether the model can even garner enough support either from the developing countries or the developed countries as it ignores limiting factors such as the availability of renewable energy resources, differences in climate and historically grown sectoral spreads, among others.

5.1.5 Multistage approach

Another option would be to follow the example of the EU and form bubbles, i.e. groups of countries that meet the target set for them collectively. The multistage

approach leads to high reductions for the USA and Central and South America. It is less restrictive for South Asia, which can follow the baseline emissions, and also for East Asia, as its per capita emissions are close to the world average. However, for Eastern and Western Africa, this case is less attractive than the C&C approach because it does not experience excess emissions (see den Elzen and Lucas, 2005).

Den Elzen and Lucas (2005) concluded that for both the reduction targets and abatement costs, the multistage and triptych approaches, and to a lesser extent the C&C approach, seem to result in the most even distribution of costs amongst all countries. Therefore they stated that those approaches will seem to provide the best prospect for a negotiation outcome based on compromises of all Parties (den Elzen and Lucas, 2005).

Another study made by Ekholm et al. (2010) analyzed global effort sharing of climate change mitigation with triptych and multistage effort sharing rules and two mitigation scenarios aiming at -10% and -50% reductions from 1990 levels by 2050, leading to concentrations of 550 ppm CO_2–eq and 485 ppm CO_2–eq by 2100, respectively. Triptych and multistage both allocate moderate reductions for Annex I and allow non-Annex I emissions to increase from 2000 levels by 2020. In 2050, Annex I faces very stringent targets around 80% from 2000 emissions, and only for the least developed non-Annex I regions the allowances exceeded their 2000 emissions (Ekholm et al., 2010).

A comparison between the economic burden the regions face and their abilities, by using GDP (PPP) per capita as wealth measure, showed that both triptych and multistage produce equitable costs, although the balance of favouring the least developed and penalizing the most developed is obviously debatable. Overall, triptych exhibited more moderate costs than multistage for Annex I while still providing gains for non-Annex I. Triptych also exhibited higher coherence, i.e. the effort of individual regions varied less from the average. This highlights that an approach not taking into account the sectoral distribution of emissions and differing mitigation potentials cannot adequately produce an equitable outcome. The coherence of triptych did, however, degrade with the more stringent target, as the allocations are then mostly based on per capita based targets also with the triptych approach (see Ekholm et al., 2010).

5.1.6 WITCH model

WITCH is a climate-economy-energy hybrid model that has been used in the past few years for the economic analysis of climate policy. It is a forward-looking model that optimizes over a discounted stream of future investment and consumption decisions; thus it features perfect foresight and has the ability to anticipate future shocks and policies and incorporate them in current decisions. It

is global, with 12 representative macro-regions that interact in a game-theoretic set up, so that their investment decisions are taken strategically with respect to other regions' choices. In addition, it incorporates technological evolution by both diffusion and innovation processes, each characterized by international spillovers. Overall, the model is well suited for investigating the various countries' economic incentives to either join or free-ride on climate coalitions, as well as for pinning down future inter-temporal effects of climate policies.

Using a numerical energy-economy-climate model Bosetti et al. (2009b) have shown that delayed participation or fast-growing countries in a global climate treaty increases the cost of climate policy. The magnitude of the penalty with respect to the ideal case of immediate participation can be large, but depends on the stringency of the target and on the possibility to temporarily breach the long-term climate objective. Technology adoption and diffusion could also be jeopardized.

Starting from the assumption that OECD countries are committed to reducing their own GHG emissions, Bossetti et al. (2009b) have analysed the best short term investment strategies for developing countries, especially for fast growing countries such as Brazil, Russia, India and China. Their results indicate that the optimal investment behaviour for emerging economies is to anticipate climate policies by roughly 10 years, and incorporate future carbon prices into short term energy investment decisions (Bosetti et al., 2009b).

5.2 Model analysis – is the best model still to be built?

The study in Article IV tried to establish what changes are required in countries' current emission intensities to achieve the contraction and convergence targets. Required future trends of CO_2 intensities were calculated by dividing the future emissions, produced with the C&C model, by the estimated future GDP. The calculation of the required changes in the emission intensities to achieve the contraction and convergence target gives interesting results (Article IV).

The calculations showed that in a world that aim at contraction and convergence, the emission intensities for most of the industrialised countries, a business as usual development, or a continuation of past development trends seems to be sufficient to achieve the target. Industrialised countries can basically follow their current trends. In this context, industrialised countries will achieve the vast reductions required in emissions mainly through shifts towards lighter economic production structures. A structural change in the production system seems to be more effective in reducing emission intensity than improvements in energy technology. However, this structural change relies partly on relocating heavy and polluting industries to developing countries, which cannot be seen as a

healthy way of development from the sustainability point of view. A globalizing economy makes it difficult to achieve an equitable allocation of emission entitlements on a national basis (Article IV).

The required future development for CO_2 intensities in most of the industrialised countries seems not to be too unrealistic. The sharp decrease in intensity after the first oil crisis was due to the increased efficiency of their energy use, plus a shift from oil to energy sources of lower carbon content. However, it was mainly due to a structural shift in the production structure, which led to lower energy intensities in their economies. The structural change of the production system seems to be more effective in intensity reduction than energy technology improvements. Economic growth has to continue its shift towards lighter sectors of the economy such as services and information and communications technology.

For the developing countries the situation is different. Many developing economies are in the industrialising phase as indicated by their increasing emission intensities. According to the C&C model, emission intensities in these countries should not grow any further, but should have been declined rapidly after 2001. The analysis indicates that industrialization based on a rapid increase in the use of fossil fuels and fast economic growth will not work in the C&C model, especially in countries with relatively high per capita emissions, such as Venezuela and Thailand. These countries are required to start to reduce their emissions intensities immediately.

But in countries like India and Indonesia, the emission intensities could have increased until 2011 and 2007, respectively. This is due to their present low levels of CO_2 per capita emissions. These countries may increase emissions from their present very low level while still remaining within the convergence path. The entitlements of India and Indonesia can grow until 2026 although their emission intensity has to start decreasing at a much earlier date.

A western type of industrialization, based on heavy industry, fossil fuel use and rapidly increasing motorized private transport, is not compatible with the C&C model. As the model does not support a development path for developing countries similar to that taken by many industrialised countries, in this sense, it does not fulfil the criteria of equity (Article IV).

5.3 Uncertainty – wicked or worthwhile?

Since all articles of this thesis were published in 2007 or before and therefore, the underlying research undertaken prior to or during 2006, the analysis do not include the latest developments in climate policy, nor in the research methods. However, they are used as an example that no economist could possibly forecast the global economy for the next 50–100 years with reasonable accuracy for the purpose of

policymaking. Forecasting the future of the energy economy for the next 50-100 years is just impossible. It is not even clear that, in general, economic forecasts for only the next 10–20 years can be relied on for policy purposes (Rosen and Guenther, 2015).

Climate system is complex, chaotic and non-linear. There are three main sources of uncertainty in these projections: the natural variability of climate; uncertainty in climate model parameters and structure; and projections of the future emissions (Dastagir, 2015). Therefore, the uncertainties reflect both the uncertainty in the underlying economic forecasts as well as the uncertainties associated with how the assumed internal operating parameters and costs of dozens of energy supply and demand technologies will change over the long run in this scenario (Rosen and Guenther, 2015). The uncertainty in projected changes by the end of 21st century is more the result of uncertainties in climate models rather than uncertainties in future emissions. However, to improve understanding of the complex interactions of the climate system, the above scenarios are useful as they provide plausible descriptions of how the future might unfold in several key areas. As stated in Moss et al. (2010), scenarios help to evaluate uncertainty about human contributions to climate change, the response of the Earth system to human activities, the impacts of a range of future climates, and the implications of different approaches to mitigation and adaptation.

However, as extensive uncertainties exist in the whole climate change issue, we should ask how our understanding of these estimates has evolved since 2001, and what we really know now. In this dissertation, estimates for future population rates with a medium variant from 2002 to 2050 were given by UN predictions, whereas future CO_2 emissions estimates for 2011 were provided by the Global Commons Institute. These estimates and the actualised population rates and CO_2 emissions for the year 2001 and 2011 by the IEA are given in Tables 3 and 4. Similarly, the estimates and the actualised CO_2 emissions per capita, GDP and CO_2 emission intensity for the same years are given in Tables 5, 6 and 7.

Table 3. Population in case study countries in 2001 and 2011.
Source: Article IV and IEA, 2015.

Country	Population (Millions) 2001	Population (Millions) 2011 (2001 estimate)	Population (Millions) 2011
United States	285,23	317,87	312,03
United Kingdom	59, 11	60,57	63,29
Germany	82, 34	82,57	81, 78
France	61, 32	62,08	65, 30
Japan	127, 13	127,84	127, 83
China	1 271, 00	1372,37	1 340,00
Venezuela	24, 87	29,41	29, 50
Thailand	63, 07	67,49	66, 58
Brazil	177,00	194,70	197,00
India	1 060,00	1188,32	1 220,00
Indonesia	212,00	240,78	244,00

Table 4. Total CO_2 emissions in case study countries in 2001 and 2011.
Source: Article IV and IEA, 2015.

Country	Total CO_2 emissions (Mt CO_2) 2001	Total CO_2 emissions (Mt CO_2) 2011 (2001 estimate)	Total CO_2 emissions (Mt CO_2) 2011
United States	5605,14	4634,83	5219,04
United Kingdom	535,54	465,16	438,73
Germany	831,51	675,88	731,41
France	368,08	335,50	310,45
Japan	1144,37	978,09	1177,89
China	3344,60	3364,03	8420,06
Venezuela	123,31	129,86	151,30
Thailand	160,00	218,72	221,78
Brazil	298,87	432,25	389,53
India	910,93	2079,86	1659,91
Indonesia	277,66	421,1	390,46

Table 5. Emissions per capita in case study countries in 2001 and 2011.
Source: Article IV and IEA, 2015.

Country	Emissions per capita (t CO_2) 2001	Emissions per capita (t CO_2) 2011 (2001 estimate)	Emissions per capita (t CO_2) 2011
US	19,65	14,58	16,73
UK	9,06	7,68	6,93
Germany	10,10	8,19	8,94
France	6,00	5,40	4,75
Japan	9,00	7,65	9,21
China	2,63	2,45	6,28
Venezuela	4,96	4,42	5,13
Thailand	2,54	3,24	3,33
Brazil	1,69	2,22	1,98
India	0,86	1,75	1,36
Indonesia	1,31	1,75	1,60

Table 6. GDP in case study countries in 2001 and 2011.
Source: Article IV and IEA, 2015.

Country	GDP PPP (billion 2005 USD) 2001	GDP PPP (billion 2005 USD) 2011 (2001 estimate)	GDP PPP (billion 2005 USD) 2011
US	19,65	14,58	16,73
UK	9,06	7,68	6,93
Germany	10,10	8,19	8,94
France	6,00	5,40	4,75
Japan	9,00	7,65	9,21
China	2,63	2,45	6,28
Venezuela	4,96	4,42	5,13
Thailand	2,54	3,24	3,33
Brazil	1,69	2,22	1,98
India	0,86	1,75	1,36
Indonesia	1,31	1,75	1,60

Table 7. CO_2 emission intensities in case study countries in 2001 and 2011. *Source: Article IV and IEA, 2015.*

Country	CO_2 / GDP PPP (kg CO2/ 2005 USD) 2001	CO_2 / GDP PPP (kg CO2/ 2005 USD) 2011 (2001 estimate)	CO_2 / GDP PPP (kg CO2/ 2005 USD) 2011
US	0,48	0,42	0,38
UK	0,29	0,30	0,20
Germany	0,32	0,29	0,25
France	0,20	0,20	0,15
Japan	0,31	0,27	0,30
China	0,76	0,44	0,70
Venezuela	0,38	0,74	0,34
Thailand	0,32	0,40	0,29
Brazil	0,17	0,28	0,16
India	0,37	0,54	0,32
Indonesia	0,26	0,49	0,21

In terms of the CO_2 emissions, the estimates for 2011 were quite exact in case of the United Kingdom, France, Thailand and Indonesia. In the United Kingdom the emissions were actually still a bit lower than estimated. Emissions for the United States, Germany, Venezuela and Japan were a bit larger (11%, 8%, 14% and 17% respectively) than the estimates whereas for Brazil and India the emissions were 10% and 20% lower than estimated. The forecasts for Japan were heading downwards from 2001 but actually their emissions were 17% bigger in 2011. The forecasts for Venezuela's emissions indicated quite even pathway whereas the actualised emissions actually grow by 14% from roughly 123 to 151 Mt CO_2. Estimates for China indicated only a slight increase, but the real growth was more than 60% to the huge 8420 Mt CO_2 that made the country the biggest emitter in this decade.

If the estimates for the population rates and CO_2 emissions were failed, the outcomes for CO_2 emissions per capita as well as CO_2 emissions intensities are clearly incorrect too. CO_2 emission intensity estimates for China and Japan (37% and 10% respectively) were lower than the actual CO_2 emission intensities in 2011. Estimates for all other countries were larger than the actual intensities. Anyhow, the calculations made in this thesis were substantially heading the right direction, but on a bigger scale. Therefore, it can be concluded that they were too audacious. What is sure is that all off the above case countries –except Thailand and Venezuela– were the top 20 emitters in the last decade, and still are.

5.4 Limitations and potentials for further research

The world has changed remarkably since the climate convention was signed in 1992. Several countries have developed massively since then. Many industrial countries are now more aware of the risks, as well as the difficulties, impacts, and opportunities of the climate change. Many developing countries have developed economically and some of them have already achieved the level of industrialized countries. At the same time, the direct effects of climate change have become commonplace and have caused serious damages in some vulnerable developing countries. There is an urgent need for adaptation measures (Wise et al., 2014).

It should be noted that substantial changes in population size, age structure, and urbanization are expected in many parts of the world this century. Statistical analysis of historical data suggest that population growth has been one driver of emissions growth over the past several decades and that urbanization and aging can also affect energy use and emissions. As the living standard rises and population continues to grow, energy use and CO_2 emissions in city areas do the same (Saidi and Hammami, 2015). Aging can reduce emissions in the long term by up to 20%, particularly in industrialised country regions. In contrary, urbanization can lead to an increase in projected emissions by more than 25%, especially in developing country regions (O'Neill et al, 2010).

Analysis made by O'Neill et al. (2010) indicates that a greater attention should be given in emissions scenarios to the implications of urbanization and aging, particularly in the key regions of the world, including China, India, the United States and the EU. These findings are motivated by the belief that better modelling of these trends would improve our understanding of the potential outlines of future energy demand and emissions.

The evidence of human impact on the climate system is now clearer and therefore, the required emission reductions have also increased. As a result, the climate negotiations are consequently becoming more and more difficult.

A number of difficult economical issues and their impact on development have been raised in international climate negotiations over the years. The necessary arrangement for climate change affects the core areas of the economy. This distinguishes the climate change agreement from other international environmental agreements and has slowed down the progress towards a comprehensive binding agreement. The progress has been hampered by the different situation of the parties, as the changes in the economic output have a big impact. According to Saidi and Hammami (2015), energy consumption is positively linked to economic growth but the impact is small.

Addressing an environmental problem by political means is never simple. And that is one of the main reasons why it has been so difficult to establish an international agreement for climate change. However, even if much have been

done regionally and locally in recent years, global negotiation and contract system is the best opportunity in trying to solve the major global climate change problem.

As noted earlier, every approach has advantages and disadvantages and therefore, it is clear that the study did not find an approach that fully satisfies all criteria at the same time. But the approaches that mix several elements receive good marks in the assessment and have a higher chance of being accepted (Falker et al., 2010). It can be concluded that a good mix of approaches can be the key to finding a broadly acceptable solution. The C&C model presented in this thesis can provide most opportunities to accommodate many views and positions (Jaeger et al., 2012). All sorts of arguments for and against C&C were mounted as it started to get traction 20 years ago. But 20 years on and in response to these, Global Commons Institute argues that C&C is now the most widely cited and the most widely supported approach in the debate aimed at achieving UNFCCC compliance. Furthermore, C&C was adopted in the UK Climate Act in 2008. However, with many concepts and ideas, it may be difficult to reach agreement upon in the negotiations. Therefore, it can be concluded that a compromise is probably the most attractive approach for all countries.

As the Kyoto Protocol is approaching its deadline, there is an urgent call for a plan for the post-Kyoto era. Actually, quite a few proposals have been put forward by scholars from many countries or institutes since 1997. Nevertheless, none of them were widely accepted in the climate negotiations, and neither was put up as a post-Kyoto mitigation proposals (Wei et al., 2013). It is necessary to have a further discussion and analysis of some globally emphasized proposals that can be widely imbibed by the policy makers in climate conferences (Bosetti and Buchner, 2009, Falker et al., 2010).

5.5 Challenges along the road to Paris

The postponement of decisions in UN climate conferences can be seen more as a rule than an exception. There were no high expectations for agreement of future commitments in last COP meeting in Lima in 2014. The main aim of the conference was to work out a draft agreement on climate change regime after 2020, which is scheduled to be finalised at the next conference in Paris 2015. Hopefully, delegates will finally obtain a binding decisions on the means of the average global temperature rise would put a stop to 2 ° C.

There are big hopes for achieving agreement for future agreement as the climate process has changed in recent years. Prior to the failed talks at COP15 in 2009, negotiators focused on securing a legally binding agreement. At COP20, they focused on a country-driven approach, where legal instruments are given less emphasis and where countries are asked to take on national commitments instead.

The recent emphasis on national actions addresses concerns by major economics such as China and India –the world's largest and third largest emitters, which industrial countries have blamed for blocking an earlier agreement. With the most populous and rapidly growing economies, Asia is becoming increasingly important in the global geopolitics. Demands arising from the rapid growth and rising per capita incomes have put tremendous pressure on the resource base as well as existing infrastructure in this region. With increasing energy consumption for meeting development requirements, India and China will be playing an important role in shaping the dynamics of future global energy and emission scenarios. For these economies, GHG emissions and climate change is being one of the major concerns. Addressing the concerns of climate change, energy use and emissions, and other development priorities simultaneously becomes a key challenge for these regions (Bazaz et al., 2014).

In many respects, the new strategy appears to have worked (Roelfsema et al., 2014). China recently announced a landmark deal to curb their GHGs assured that their emissions will begin to fall in 2030. The study by Green and Stern (2015) shows that China's emissions could actually peak already by 2025 as the country has entered a new phase of economic development. From structural changes in the economy to explicit policies on efficiency, air pollution and clear energy, China's new development model is continuing to promote economic growth while driving down its GHG emissions (Green and Stern, 2015). The United States is also proceeding on its own way. President Obama announced that the United States will reduce greenhouse gas emissions by 26 to 28% below 2005 levels by 2025.

These developments have led to renewed optimism amongst negotiators. However, the gap between the industrialized and developing countries has not expired. Industrialised countries require polluters such as China on an equal footing, according to the climate effort, whereas developing countries refer to the back on, and the fact that industrialised countries emissions have caused the whole climate problem in the first place. In addition, the developing countries require that the industrialised countries have to finance the climate work. Technological development and the combination of emissions trading schemes need also to work satisfyingly on the climate negotiations.

The ongoing negotiations will need to satisfy the interest of both the rich and the poor countries in regard to finance mechanisms. The fact remains that a new way forward has been established in which all countries participate and which therefore holds promise of meaningful global action to address the threat of climate change. The negotiations in Lima in 2014 turn out to be among the most valuable steps in two decades of international climate negotiations.

The pursuit of a carbon-neutral world in 2050 sounds promising but ambitious. The two-degree target is a year by year more difficult to reach. The degree is not a trivial number. It shows in sea level elevation, public health, competitiveness and

security policy - especially in countries that emission agreements oppose the most. If COP meeting in Paris does not give concrete results, a multilateral negotiation system is at risk.

5.6 The bottom line

It seems evident that no single criteria can lead to acceptable solution from every perspective. Any approach will have to face objections from one side or the other. The approach that will have a chance of being acceptable to all parties will have to face critism and objections on its component elements from all sides, and be able to satisfy these in a balanced manner, not giving one side an advantage over the other. Equitable efficiency is difficult to achieve, but it is still worth trying to find solutions, which could meet both the equity targets and the efficiency targets.

It is possible to construct burden sharing models, which try to take into account several aspects related to both equity and efficiency. However, the models may easily become very complex, if all the different natural circumstances and aspects are tried to be covered. The differences in natural resources vary so much between countries that it would require hundreds of compensating factors to be taken into account and still the results could be questionable. In addition, the complexity of the model will certainly hinder the possibilities for political acceptance because the various exceptions may easily lead to bargaining and disputes of the results.

Acceptance of the burden sharing model from as many parties as possible would be important to achieve vast enough coverage and participation in order to be able to carry out required mitigation actions. It may, however, be very difficult to find a model, which could offer such incentives for all the stakeholders to participate. Disastrous climate change related catastrophes are sometimes seen as the only possible agent strong enough to carry out required changes in the priorities of the decision makers. To avoid these catastrophes, it is worth researching burden sharing models and approaches further in order to find a model which will satisfy all parties.

6 CONCLUSIONS

This thesis aimed at analysing and unravelling various options for future development of the international emission reduction regime. The main findings can be concluded as follows:

1) The results from developing Southern Asian countries and Latin American countries demonstrate that there are unravelled differences between these countries in terms of their energy use and emissions. The different characteristics stem from the varying structure of their energy economies. Primary energy requirements depend on factors such as level of industrialization, economic structure, level of motorization, average climate and domestic energy endowment. In India the CO_2 intensity level has declined since the middle of the 1990s due to the fact that the fuel mix has changed towards less carbon intensive energy production system and created lower CO_2 emissions. Although the population growth in India has been rapid (75% increase from 1973 to 2001) and contributes considerably to the total growth of emissions, the country has very low per capita CO_2 emissions (1,59 tons in 2010).

   The results indicate that in the selected Southern Asian countries, CO_2 emission intensity has declined since the latter period of 1990s, whereas in the selected Latin American countries the CO_2 intensity of the economies fluctuated without a clear trend, with the exception of Mexico, where the CO_2 emission intensity increased in the 1970s and 1980s, and then turned to decrease indicating that the production structure in the Mexican economy has become lighter.

2) Generally speaking, the increase in CO_2 emissions demonstrated in this work can be attributed partly to economic growth and partly to population growth. The structural shift from rural to manufacturing economy resulted in increasing energy demand. The main drivers of change in developing country intensities can be policies and measures, or external shocks that affect a country's economic structure, energy efficiency, and fuel choices. Also, shifts in economic activity from lower to higher carbon intensity sectors, as well as technological development, contribute to variations in intensity trends. However, the main aim for most developing countries is to lower the CO_2 intensity of their economies, rather than reduce absolute emission levels *per se*. Most importantly, when assessing the absolute intensity levels and their changes over time, one should assess country's performance relative to itself rather than make international comparisons.

3) The thesis analysed five alternative methods of how the burden could be shared among nations after the Kyoto Protocol. The C&C approach is ultimately based on a combination of the egalitarian and sovereignty principles, leaving aside the principle of responsibility. The Brazilian proposal is clearly oriented to the responsibility, whereas the multistage approach is based on a combination of the responsibility and capability principles. The latter may also include elements related to the egalitarian principle, for example, by using per capita emissions levels as the burden-sharing key. The triptych approach is based mainly on the capability to act, but also encompasses elements of the egalitarian equity principle. Even if the various burden sharing models can be criticized on many grounds, they can be seen as complementary models of global responsibility.

4) The thesis produced a new burden sharing approach, the C&C model, which takes into account GDP. The results demonstrate that in most industrial countries the decreasing trends in CO_2 intensity, after the oil crisis in the 1970's, would have been sufficient to reach the C&C target. However, the trends in the 1990's have usually not been sufficient due to weaker than current energy policy measures. The rapidly industrializing countries of Southern Asia and Latin America (e.g. Thailand and Venezuela) will have to lower their CO_2 intensity trends significantly to reach the C&C target, while some other developing countries, such as India and Indonesia, are in fact currently at the turning point were they have to start decreasing their CO_2 intensity. C&C model is a practical tool for the evaluation of the Kyoto climate policy process and global climate change negotiations from the perspective of the developing countries.

   A comprehensive model with rationally defined targets, the C&C approach is a strong candidate for a global solution to the burden sharing problem. The model has the potential to provide a framework for a genuine long-term solution to required emission reductions, reducing political risk and offering businesses and investors the sort of a preferred predictable framework they prefer. The target provided by the model seems plausible for industrialized countries due to the possibilities offered by structural change. Most developing countries can adjust their development policies to fit in the framework quite well. In practice, however, the presently dominating development paradigm does not sufficiently emphasize environmental aspects and therefore, an agreement is difficult to reach.

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