Università
Ca'Foscari
Venezia

Corso di Dottorato di ricerca in Scienza e Gestione dei Cambiamenti Climatici
ciclo XXX

Tesi di Ricerca

The Equity and Development Dimensions in the Paris Agreement

Assessment and policy responses

SSD: SECS-P/01 ECONOMIA POLITICA
SECS P/02 POLITICA ECONOMICA

Coordinatore del Dottorato
ch. prof. Carlo Barbante

Supervisore
ch. prof. Carlo Carraro

Dottorando
Marinella Davide
Matricola 956155

The Equity and Development Dimensions in the Paris Agreement

Assessment and policy responses

Marinella Davide
PhD program in Science and Management of Climate Change
Ca' Foscari University

Summary

This doctoral dissertation investigates equity and development issues in the context of the Paris Agreement. It first provides an overview of the main elements of the Paris Agreement, complemented by an assessment of how the equity principle is addressed in the final text and how its implementation has evolved over time within the UNFCCC process. The analysis then evaluates the Nationally Determined Contributions (NDCs), which represent a crucial element of the agreement, according to different metrics based on equity. The third chapter uses a recursive-dynamic Computable General Equilibrium model coupled with an empirical analysis on past data to quantitatively estimate the future impacts of the mitigation objectives, included in the NDCs, on developing countries' poverty and inequality, emphasizing also the relationship between climate change and two important Sustainable Development Goals. The research then explores the role of climate finance tools in offsetting potential trade-offs induced by the climate policy, focusing in particular on the effects of different allocation schemes of the Green Climate Fund on GDP and clean energy deployment. Overall findings suggest that the concept and implementation of the equity principle within the UNFCCC changed over the years, with the Common but Differentiated Responsibility losing its initial influence. Although the Paris Agreement abandoned the Annex I/non-Annex I countries dichotomy, the new language is not clear enough to avoid future challenges. In addition, the mitigation contributions proposed by countries are far from being consistent with the objectives of the Paris Agreement in terms of both stringency and equity. A significant gap affects the NDCs of major emitters with the only exception of India. Looking at the development opportunities, the analysis shows that the Paris Agreement is projected to slow down poverty reduction efforts, especially in countries that proposed a relatively more stringent mitigation objective. The aggregate effect, however, is not so broad. Conversely, potential synergies emerge between climate change interventions and within-country income inequality. Finally, the Green Climate Fund can play an important role in compensating for the cost of climate policy, even though the current distribution of funds could not incentivize countries to propose more ambitious emission reduction targets.

Table of Contents

List of Figures

List of Tables

Keywords and Abbreviations

Annex I countries: countries included in the Annex I of the UNFCCC. It includes the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States. Often referred also as countries part of the Annex B of the Kyoto Protocol.

Non-Annex I countries: mostly developing countries, not included in the Annex I, as defined by the UNFCCC.

BaU: Business as Usual

CBDR-RC: Common But Differentiated Responsibilities and Respective Capabilities

CGE: Computable General Equilibrium

COP: Conference Of the Parties

GCF: Green Climate Fund

GDP: Gross Domestic Product

GHG: greenhouse gas

GTAP: Global Trade Analysis Project

IAM: Integrated Assessment Model

ICES: Intertemporal General Equilibrium System

(I)NDCs: (Intended) Nationally Determined Contributions

ITMOs: Internationally Transferred Mitigation Outcomes

IPCC: Intergovernmental Panel on Climate Change

LDCs: Least Developed Countries

RCP: Representative concentration pathways

RtD: Right to development

SIDS: Small Island Developing States

UNFCCC: United Nations Framework Convention on Climate Change

UNGA: United Nations General Assembly

VA: Value Added

WRT: With Reference To

Introduction to the dissertation

The Paris Agreement, adopted at the end of 2015, has been welcomed as a turning point in climate policy negotiations. After the failed attempt of the Copenhagen climate conference in 2009 and four years of groundwork starting in 2011 in Durban, countries finally adopted "a protocol, another legal instrument or an agreed outcome with legal force" applicable to all the Parties to the UNFCCC. The Paris Conference (COP21) accomplished this task by delivering a global agreement that requests the international community to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, but also includes important adaptation and low-carbon finance objectives. Formalizing a new approach to international climate policy, the Paris Agreement represents a point of departure from the past. Its bottom-up nature would require new governance structures to be built and the existing ones to adapt to new future challenges. Among these, aligning the "Nationally Determined Contributions" (NDCs), a spectrum of climate plans which take together quantitative economy-wide emission reductions and sub-national adaptation strategies, with the long-term temperature objectives is a crucial issue. Recognizing equal dignity of all contributions, the Paris Agreement overcome the traditional, static dichotomy between Annex I and non-Annex I countries' commitments, opening the door to a flexible structure, where emerging and developing countries are the new crucial actors in the fight against climate change.

Starting from these premises, the present dissertation aims to analyze the Paris Agreement, particularly the mitigation component of NDC's through the lens of equity and development.

In five chapters, the dissertation addresses different crucial aspects connected to the implementation of the NDCs. The first two chapters provide an overview of the Paris Agreement and the equity implications in the context of climate change. After reviewing the key provisions at the base of the newly-launched international climate regime, the role of the Right to Development in the climate negotiations is explored. Particular attention is given to the evolution process that led the Right to Development to enter the climate debate through the formalization of the Common but Differentiated Responsibilities principle, as a cardinal notion to balance environmental and development instances. These two issues are strongly and mutually related, if it is true

that the disruptive effects of unmitigated climate change are likely to pose a threat for the development of countries, then the climate policy action may be a hurdle to the fulfilment of this right, especially for the vulnerable and less advanced economies. On the other hand, industrialized nations have benefitted from an unrestricted development over the past decades, which emerging economies are now in the path to replicate. From an initial recognition of the special situation of developing countries, the issue has turned out to be a major obstacle to the advancement of the climate cooperation. How these ethical aspects have been integrated within the UNFCCC and in which manner the Paris Agreement's new provisions incorporate them are the primary research questions that the first part of the dissertation aims to answer.

Building on the conceptual effort of the first two chapters, the third one evaluates the NDCs proposed by countries according to different metrics based on equity. In particular, the mitigation targets included in the NDCs are compared to a carbon budget consistent with the objective to keep global temperature below 2°C allocated to single countries according to three equity indicators. After reviewing the literature on the operationalization of equity in the context of climate change, the most relevant and feasible approaches are used as the basis to assess NDCs and quantify the emission debit or credit of each country or region. This chapter enriches the ongoing policy and academic debate by providing a transparent method to evaluate proposed actions of a broader number of countries than previous research efforts.

The fourth chapter examines the impacts of the climate change policies on developing countries' poverty and inequality. More broadly, it explores the relationship between the Paris Agreement and two key Sustainable Development Goals (SDGs), with the objective to understand the potential co-benefits and side-effects emerging from these new international policy settings. In particular, this chapter provides a quantitative estimate of future impacts of the mitigation objectives included in the NDCs on extreme poverty headcount and income inequality of less developed countries. Results are compared with a Business as Usual scenario without climate policies as well as with a scenarios including international financial support to developing countries' climate change action.

As an extension to the previous chapter, the final chapter further investigates the role of climate finance tools in offsetting potential trade-offs induced by the climate

policies. Starting from the assumption that climate finance mechanisms are crucial in supporting the achievement of long-term climate goals, and to potentially transfer significant resources to developing countries, this chapter quantifies the effect of different allocation schemes on GDP and clean energy deployment. The exercise is built upon the main features of the Green Climate Fund to gain useful insights on its functioning in the context of the Paris Agreement.

From a methodological point of view, we rely on both qualitative and quantitative methods. The first part of the dissertation (Chapters 1 and 2) is structured around a content analysis of the Paris Agreement and a literature review of the theoretical debate on equity and development. The second part (Chapters 3 to 5) primarily relies on quantitative tools. Specifically, a recursive-dynamic Computable General Equilibrium (CGE) model is used to estimate the different climate policy scenarios and their economic impacts. When needed, such a tool is complemented by the most appropriate methods given the specificity of the research question to address, respectively an indicator analysis to allocate different carbon budgets in the third chapter and an empirical analysis of historical data of poverty and inequality measures in the fourth one. The analyses have global coverage, with the only limitation of the regional aggregation foreseen in the CGE model.

Beyond contributing to the research efforts followed to the adoption of the Paris Agreement, the ultimate goal of the present dissertation is to provide policy-relevant recommendations to inform the ongoing and future international climate policy debate, including the global stocktake process which will be launched soon to assess the progress toward the achievement of the Paris Agreement's objectives.

The manuscript follows the structure outlined above, where the chapters are conceived both as logically connected one to the each other but can also be considered single peer-reviewed quality essays, whose methodology and results are individually illustrated and discussed.

Climate policy after Paris: assessment and perspectives

Introduction

The 21st Conference of the Parties to the UNFCCC (COP21), held in Paris in December 2015, closed with the adoption of the Paris Agreement, the long-awaited global deal aimed at strengthening the international action against climate change.

The road to Paris had been long and tortuous, characterized by a tough debate that dates back to 2007, when the Bali Action Plan defined the main issues at stake. Even though the COP15 in Copenhagen in 2009 was not able to deliver the expected results, it contributed to realize that a new narrative was needed and, starting from the following Conferences of the Parties in Cancun and Durban, to launch the basis of the current bottom-up approach. In particular, in 2011 the COP17 in Durban established that the aim of the 2015 summit should have been to "develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties" to be operative from 2020 (UNFCCC, 2011).

Against this background, the debate around four main issues proved to be particularly difficult: i) new mitigation commitments for the post-2020 period ii) financial support to be provided to developing countries iii) adaptation and loss & damage (L&D), and iv) the legal form of the outcome.

However, after two weeks of negotiations the Paris Conference successfully managed to close years of negotiations. Expectations were high as the Conference was considered by many the last chance for the UNFCCC to demonstrate the ability to deliver a coordinated climate action after years of delay. For this reason, soon after COP21 President Fabius gaveled its adoption, the Paris Agreement was applauded as a landmark and historical step from both the United Nations officers that worked for it and the majority of Ministries and government leaders attending the conference.

The final outcome is composed of two parts: the Paris Agreement, an 11-page document outlining major legally-binding provisions, is attached to the "decision

adopted by the COP" that sets conditions and provides more details for the adoption of the agreement even if with weaker legal language (UNFCCC, 2015). As a key component to reach the compromise, the Paris deal puts together top-down elements, composed of the provisions related to the future long-term process, and a bottom-up approach that allows national governments to decide about concrete actions to be implemented.

This essay describes and discusses the main outcomes of the Paris Conference. It first provides an overview of the main elements of the Paris Agreement's text to then assess them in terms of effectiveness, coherence and future prospects.

The Paris Agreement: main contents

The Paris Agreement aims at strengthening the global response to climate change by defining three main objectives. First of all, it calls for keeping "the increase in the global average temperature to well below 2 °C above pre-industrial levels" with aspirational "efforts to limit the temperature increase to 1.5 °C" since "this would significantly reduce the risks and impacts of climate change" (UNFCCC, 2015).

Second, it aims at "increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience".

Finally, it calls for mobilizing consistent "finance flows" with the established mitigation and adaptation goals.

To achieve these objectives, the agreement establishes a common instrument, applicable to all countries, composed of "nationally determined contributions" (NDCs), that will set progressive ambitions in time, with certain flexibility recognized to developing country Parties.

Emissions reduction

As for the mitigation objective, the deal calls for a global peaking of greenhouse gas (GHG) emissions to be reached "as soon as possible", recognizing that peaking will take longer for developing country. Rapid reductions would then be undertaken, in accordance with the best available science, in order to reach, after 2050, a "balance" between emissions from anthropogenic sources and removals by sinks (Article 4, UNFCCC 2015).

The NDCs that each country "intends" to achieve shall be prepared, communicated and maintained by all parties, "reflecting the highest possible ambition", but also the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC). As requested by developing countries over the whole two weeks of negotiations, a certain level of differentiation remains: developed countries, indeed, "should continue taking the lead by undertaking economy-wide absolute emission reduction targets" whereas developing nations should "continue enhancing their mitigation efforts" with the encouragement to move towards economy-wide emission reduction targets. Further flexibility is allowed to the Least Developed Countries (LDC) and Small Island Developing States (SIDS) that "may prepare and communicate strategies, plans and actions for low greenhouse gas emissions development reflecting their special circumstances".

The contributions will be communicated every five years and recorded in a public registry maintained by the UNFCCC. They shall aim at a progressive increase of the ambition.

The document also recognizes the possibility to embark on voluntary cooperation (Article 6., UNFCCC 2015), including "the use of internationally transferred mitigation outcomes" (ITMOs)(Article 6.2). It also establishes a new mechanism, which aims to contribute to the mitigation of GHG emissions and support sustainable development (Article 6.4) as well as the creation of non-market mechanisms to assist Parties in the implementation of NDCs "in context of sustainable development and poverty eradication" (Article 6.8). Learning from the past experience with flexible mechanisms launched with the Kyoto Protocol, the new mechanism will allow for participation of both public and private entities, and shall aim at delivering an overall reduction in global emissions.

Adaptation

A global qualitative goal of "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" is included in Article 7 of the Paris Agreement. This article defines adaptation as a multi-level global challenge, from local to international, as well as a key component of the response to climate change in the long term. It also explicitly recognizes the synergy with mitigation strategies by calling for an adequate adaptation action "in the context of the temperature goal" and by

emphasizing that "greater levels of mitigation can reduce the need for additional adaptation" and the associated costs. The agreement therefore highlights key adaptation principles, indicating that the approach should be "country-driven, gender-responsive, participatory and fully transparent" and guided by the best available science but also traditional and local knowledge.

Through a cycle of action similar to that of mitigation, all Parties are called to submit and periodically update an adaptation communication (AC), to be then recorded in a public registry maintained by the UNFCCC secretariat. The process is, however, designed to be flexible both in terms of form and timing.

While negotiations on adaptation were largely characterized by a constructive and collaborative spirit, the same did not apply to the related issue of Loss & Damage. The concept of L&D refers to the negative impacts materializing in vulnerable developing countries when both mitigation and adaptation fall short. It has been among the hottest topics to be dealt with by the UNFCCC in recent years because of its connection to the contested discourses on historical responsibility/liability and compensation.

The final outcome in Paris saw Loss & Damage to obtain a stand-alone article (Article 8, UNFCCC 2015), consistently with the repeated claims of developing countries, and SIDS especially, for it to be something beyond adaptation and thus to be treated with separate tools. The article recognizes the importance of minimizing and addressing Loss & Damage, and the role of sustainable development in reducing the associated risk. The article recall the Warsaw International Mechanism (WIM), created in 2013 to advance knowledge gathering, coordination and support on the topic, leaving the door open for it to be "enhanced and strengthened" in the future. It also calls UNFCCC Parties to work cooperatively to enhance understanding, action and support in areas including early warning systems, comprehensive risk assessment and management, risk insurance facilities, climate risk pooling, and non-economic losses. However, since the issue continues to be at the center of a heated debate, opposing especially the US and small island representatives, the compromise language in the agreement is somehow balanced in the text decision (paragraph 52), which states that Article 8 should not "involve or provide a basis for any liability or compensation" claim. The solution, however, caused a divide among developing countries.

Low-carbon finance

Also climate finance was one of the most debated issues before and during COP21. Through Article 9, developed countries confirmed their existing financial obligations towards developing countries and committed to "continue to take the lead" in mobilizing financial resources from different sources (both public and private) at a pace that should increase over time. This comes with the binding commitment to report every two years the financial support disbursed and planned. In the accompanying COP text decision, Parties agreed that the current goal of mobilizing US$100 billion per year by 2020, to be transferred from developed to developing countries, will be maintained for an additional five years and prior to 2025 a new collective goal will be agreed keeping the 100 billion figures as a floor. The article for the first time encourages contributions also by other countries on a *voluntary* basis.

The Agreement (under Article 13.10, UNFCCC 2015) finally calls for developing countries to provide "information on financial, technology transfer and capacity-building support needed and received" to implement their mitigation and adaptation plans.

Means of implementation

On technology and capacity building the agreement calls for a stronger approach and introduces some novelties, leaving however upon the next UNFCCC meetings the task of establishing clearer details and procedures. As for technology, Article 10 establishes a new framework under the current UNFCCC Technology Mechanism to foster action on technology development and transfer and to support developing countries.

The important role of capacity building was stressed in the agreement as a key precondition for reaching the Paris goals. Article 11 sets the commitment to enhance the capacity and ability of developing country Parties to implement adaptation and mitigation actions and to assist them in meeting the transparency criteria required to communicate mitigation and financial information.

The Global Stocktake and Transparency mechanisms

The mechanism that will guide countries towards the achievement of the Paris objectives is the "global stocktake", a periodical review of progress established under Article 14 (UNFCCC, 2015). Every five years it will assess the collective effort from all countries and compare it with the long term goals in terms of mitigation, adaptation

and finance. Information will concern all the areas covered by the Paris Agreement, including the aggregated effect of NDCs, the adaptation efforts, the mobilization and provision of financial, technology and capacity building support, the latest available reports by the IPCC. In order to ensure emission reduction pledges will be more and more stringent over time, the outcomes of the global stocktake shall directly inform countries in the process of updating their national contribution.

The first global stocktake is planned to take place in 2023 but all Parties will convene earlier in 2018 for a "facilitative dialogue" to start informing the preparation of national contributions before 2020.

The two linked processes (the global stocktake and the recurring communication of increasingly ambitious contributions) are the only instruments envisioned to put pressure on countries in undertaking mitigation and adaptation efforts, as the compliance mechanism established to monitor the implementation of climate pledges is explicitly "facilitative" and "non-punitive".

These procedures constitute not only the core obligations envisioned by the Paris Agreement but are also part of the transparency framework. All Parties, with the exception of the LDC and SIDS are, indeed, required to report inventories and information on the implementation of their contributions in order to be submitted to the expert review and multilateral assessment of progress.

Legal issues

As widely expected even before the Conference, the Paris Agreement formalizes a hybrid architecture, combining legally binding elements and aspirational provisions. The legal obligations concern the framework and the procedures: countries are required to develop and communicate their NCDs every five years, to report their national GHG emissions and carbon sink capacity and, only for developed countries, their financial efforts. In order to allow the maximum participation possible, the text of the agreement does not include explicit binding emission targets or new binding quantified financial commitments. In addition, no sanctions are considered in case of non-compliance, since the system will be rather based on peer pressure and shared awareness.

From the legal point of view, the rules for the Paris Agreement to enter into force are established at "the thirtieth day after the date on which at least 55 Parties to the Convention accounting in total for at least an estimated 55 percent of the total global greenhouse gas emissions have deposited their instruments of ratification, acceptance, approval or accession" (Article 21, UNFCCC 2015).

Beyond the words: assessing the main elements of the Paris Agreement

The Paris Agreement represents the result of years of negotiations and compromises between different countries with very different priorities and interests. Both the UNFCCC and the French COP Presidency in particular, had been very successful at capturing the political momentum. However, it is interesting to take a closer look at the provisions included into the Paris Agreement both in terms of their role in progressing the elements of the current regime as well as in projecting their potential effect in the near- and long-term future.

A matter of differentiation

Differentiation is certainly not a new issue within the UNFCCC debate. Even though the Annex I/non-Annex I distinction included in the Framework Convention and recalled in the Kyoto Protocol was clearly no longer acceptable, years of negotiations struggled in finding a new paradigm reflecting the current global economic picture. In Paris all Parties agreed that the new deal needed to somehow reflect current differences in countries' conditions and responsibilities. The final outcome, however, represents the compromise among two main opposite views: on the one side, the majority of developed countries supported the view that the concept of NDCs already implies a sort of self-differentiation, on the other side developing nations opposed an agreement with "symmetric" provisions for all the participants.

The issue is crucial for the practical implementation of provisions such as mitigation contributions, progress and reporting of mitigation actions, accounting framework and financial support. The Paris Agreement's language finally managed to mark a step beyond the Kyoto's Annexes, where commitments and countries were strictly grouped, towards a more flexible approach. All Parties have equal obligations, particularly for key provisions including NDCs communication, transparency and the global stocktake, but the Agreement distinguishes between developed countries, that

are required to take the lead, and developing countries to which some differentiation in terms of timing and typology of action is allowed. The principle of "common but differentiated responsibilities and respective capabilities" (CBDR-RC) is often recalled, actually preserving a link with the concept of differentiation originally included in the 1992 Framework Convention, coupled, in the case of LDCs and SIDS, with the need to take into account national circumstances.

However, no clear definition of developing and developed countries is provided, leaving the ground for different interpretations, if the issue will not be addressed in the future.

Long-term emission scenario: what is the contribution of (I)NDCs to global carbon emission reduction?

Contrary to the Kyoto Protocol, the Paris Agreement's mitigation objectives are not framed in terms of quantified emissions reduction limitations. It indeed defines temperature limits ("well below 2°C" and the aspirational "efforts towards 1.5°C") and gives directions on the long-term trends (peaking of emissions followed by rapid reductions), including a "balance" between carbon emissions and removals. In addition, there is no clear time horizon to achieve these objectives but the language, which includes terms like "as soon as possible", seems to have been intentionally left ambiguous.

More specific, climate targets are included in the text indirectly, through the language that requires each Party to the Agreement to submit and regularly update its NDC. In a process that started well in advance the Paris meeting took place, world governments had firstly submitted their "intended" nationally determined contributions (INDCs), followed at the time of ratification of the agreement by the official NDC. In particular, as of September 30, 2017, 160 Parties have submitted their first NDCs, whereas the INDCs that were received by the UNFCCC were 190. All together the INDCs cover around 99% of global GHG emissions (WRI, 2016).

As for participation, the Paris Agreement can be therefore considered a success, since it manages to have major emitting countries such as China, United States, European Union, India and Russia on board. However, the overall picture is rather complex.

According to the latest assessment released by the UNFCCC on May 2nd 2016, all Parties included information on their contribution to carbon emission reduction, even though their structure and content vary consistently (UNFCCC, 2016). Developed countries generally express their contributions in the form of an absolute quantified economy-wide mitigation target, which represent 32% of the total contributions. Conversely, most of developing countries usually link their emission reduction target to a Business-as-Usual (BaU) scenario (45% of the INDCs) or formulate their pledges in terms of emission intensity (4%) or peaking year (2%). Among the latter there are also 20% of countries that do not specify a quantitative emission reduction commitment, while they describe actions and policy currently in force or planned to be implemented in the future (UNFCCC, 2016). In addition, most of developing countries proposed both an unconditional mitigation component and a more ambitious action, conditional to the provision of finance, technology or capacity-building support from the international community.

The wide heterogeneity of contributions, however, makes the attempt to compare the aggregate ambition of the efforts proposed under the Paris Agreement rather challenging and uncertain.

According to the UNFCCC (2016), emission growth resulting from the implementation of the proposed INDCs is expected to slow down by a third in the 2010–2030 period, in comparison with the 1990–2010 period. In particular, the global emission level resulting from the INDCs is estimated to amount on average to 56.2 Gt CO2eq in 2030, an increase in the range of 34–55% compared to 1990 levels or of 8–23% in relation to 2010 global emission levels.

Although not trivial, the mitigation actions that have been submitted will not be sufficient to keep the world's temperature increase below the 2°C trajectory. In this regard, the report affirms that aggregate projected emissions resulting from the INDCs in 2030 are expected to be higher by 36% (range 24–60%) than the emission levels required under the least-cost 2 °C scenarios.

Even before the agreement was adopted, other studies have tried to assess the impact of INDCs on global temperatures and their consistency in reaching the objective to keep global warming below 2°C above pre-industrial temperatures. Overall these assessments confirms that they should be seen as a first step towards the foundation

of an ambitious global climate action but for now are not sufficient to remain under the 2°C threshold.

Table 1 summarizes and compares five of these research efforts: the official UNFCCC assessment report, the UNEP Gap Report 2015 (UNEP, 2015), the Climate Action Tracker (CAT, 2015), Climate Interactive's "Climate scoreboard" (Climate Interactive, 2015), the energy related estimates provided by the International Energy Agency (IEA, 2015).

In particular, the analyzed studies estimate an emissions gap between the full implementation of unconditional INDCs' mitigation actions and the least-cost emission path to the 2°C target in 2030 in the range of 14 - 16 Gt CO2eq on average. These figures are in some cases then translated into estimated temperature increase above pre-industrial levels in 2100. Temperature values range from 3.5°C, as assessed by UNEP and Climate Interactive to a more optimistic scenario projected by both CAT and the IEA leading to 2.6/2.7 °C. The difference in temperature estimates can be explained by the assumptions that these models take into account, especially concerning the post 2030 period. Specifically, CAT assumes that similar levels of effort will be undertaken after 2030, whereas Climate Interactive, and presumably also UNEP, assume no further action after 2030.

Table 1. Comparison of estimates of global emission gap and global temperature according to different tools

	UNFCCC	UNEP	CAT	CLIMATE INTERACTIVE	IEA[1]
Global emission gap to 2°C target by 2030 (median)	15 Gt CO2 eq	14 Gt CO2 eq	16 Gt CO2 eq	14 Gt CO2 eq	N/A
Global temperature by 2100	N/A	3.5° C	2.7° C	3.5° C	2.6° C

UNEP's assessment also points out that these pledges do not present a veritable increase in ambitions as compared to current policies. In fact, the emissions resulting

[1] Note that IEA reports only estimate for energy and process-related emissions, so they are not included in calculating the average value.

in 2030 from the INDCs are projected to be only 4 Gt CO2eq lower than the levels determined by current policies and therefore "far from enough", according to the UN agency (UNEP, 2015). On the other hand, however, CAT's projections indicate that current governments' initiatives are not fully consistent with the 2030 pledges, meaning that further measures are necessary to achieve the mitigation targets stated in the INDCs (CAT, 2015).

The IEA (2015) also adds that following the INDCs submitted so far, and the planned energy policies in other countries, the world is likely to consume the carbon budget consistent with a 2°C scenario by around 2040, thus eight months later than under current policies.

The Paris Agreement clearly recognizes that a more ambitious reduction effort will be required. It should be reminded, indeed, that NDCs are the result of a compromise reached to have a wide participation, including both key emitting countries and developing nations.

The key mechanism aimed at addressing this gap is the 5-year update process, which needs to be consolidated in the next few years, and the fact that it should be informed by the results of the assessment coming from the global stocktake. However, the only formal incentive for countries to increase stringency of their contributions relies on the language on "progression" over time and reflecting respective "highest possible ambition". Overall, the wording of Article 4 seems to have a weak prescriptive status and, as the whole NDC complex, will depend on single countries' initiative and on how robust will be the enforcement of the stocktaking process as well as of the transparency system. In addition, as the implementation of the upper-bound commitments proposed by developing countries will depend on the amount of international finance and technology received, an important element determining the future ambition of the Paris Agreement will be also its ability to mobilize financial and technological support.

A comparative analysis of mitigation efforts

Since mitigation actions included in the (I)NDCs are expressed by using different metrics, it is difficult to compare the single efforts proposed by countries. To facilitate

this task, Table 2 shows the emission reduction targets proposed by the top ten emitting countries by putting them on an equal footing.

Estimated figures show that, when emission reduction targets are compared to 1990, the European Union stands out as the most ambitious in terms of stringency of commitment. On the contrary, both China and India are projected to crucially increase their GHG emissions in absolute terms in 2030, especially compared to 2005 levels. Of course, since China and India have proposed a reduction in terms of CO2 intensity, the assessment is highly influenced by the GDP estimates in 2030. In particular, the degree of change clearly depends on the assumptions about the GDP growth rate in 2030[2] (see column 7-8 of Table 2). Both countries have been experiencing an extremely high growth in GDP and GHG emissions in recent years; however, China's emission intensity is higher than that of India, and is projected to be higher even in 2030 (Ray et al. 2015).

Emission reduction figures significantly change when all the proposed efforts are compared in terms of carbon intensity (i.e. normalized on GDP). In this case, Indonesia, Brazil and Russia commit themselves to the highest reduction levels (with a decrease in emission intensity by 93, about 87, and 86% respectively). At the opposite side of the ranking there are Japan and India that, with a decrease in emission intensity of GDP of around 30% or slightly above, show the least ambitious targets. The European Union, the United States and Canada present a similar reduction in emission per GDP, slightly above 55% compared to 2005 levels. As a general trend, developing countries commit to the highest mitigation efforts per unit of GDP. This can explain the reason China and India prefer to express their NDCs in terms of reduction per GDP.

[2] Section (a) uses the data on GDP estimates for 2030 issued by the Socioeconomic Pathway 2 (SSP2), while section (b) employs data by the Energy Technology Perspectives (ETP) of the International Energy Agency. The growth rate estimated by the first model is higher than the second one and the difference affects results in comparing the reduction commitments of India and China, which are expressed in the form of emission intensity (i.e. normalized on GDP). Data are available at https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about (SSP) and http://www.iea.org/etp/etpmodel/assumptions/ (ETP).

Table 2. Comparison of INDCs according to different metrics

COUNTRY	(I)NDC			DATA for base year		Equivalent pledges (excl. LULUCF)		
	GHG reduction (%)	Base year	Target year	GHG emissions [MtCO2eq]	Emissions intensity [MtCO2eq/ 2005 trillion US$]	Change wrt 1990	Change wrt 2005	Change in intensity wrt2005 [MtCO2eq/2005 trillion US$]
Brazil	-43	2005	2030	840,19	941,92	-15	-43	-87
Canada	-30	2005	2030	722,57	620,76	-11	-30	-56
China	from -60 to -65*	2005	2030	7.345,03	3238,55	**(a) SSP2 data:** from +1046 to +1210	**(a) SSP2 data:** from +418 to +492	from -60 to -65
						(b) ETP data: from +384 to +453	**(b) ETP data:** from +119 to +150	
EU	-40	1990	2030	5.235,35	511,76	-40	-37	-57
India	from -33 to -35*	2005	2030	2.081,93	2496,32	**(a) SSP2 data:** from +1499 to +1548	**(a) SSP2 data:** from +851 to +881	from -33 to -35
						(b) ETP data: from +475 to +493	**(b) ETP data:** from +242 to +253	
Indonesia	-29	BAU	2030	2881,00	946,15	422	226	-93
Japan	-26	2013	2030	1344,58	294,22	-16	-26	-29
Mexico	-22	BAU	2030	1110,00	416,01	99	32	-75
Russian Federation	from -25 to -30	1990	2030	2.776,78	3293,93	from -25 to -30	from -3 to -9	from -86 to -87
USA	from -26 to -28	2005	2025	6.841,50	522,53	from -14 to -17	from -26 to -28	from -54 to -55

What's next for international carbon markets?

In a further effort to increase ambition, the Paris Agreement recognizes the possibility to embark on voluntary cooperation, including "the use of internationally transferred mitigation outcomes" (ITMO). In theory, these "cooperative approaches" will allow all Parties to the agreement to engage bilaterally or multilaterally in different types of international cooperation on mitigation, sustainable development and possibly also adaptation. Even if the term "markets" is not explicitly mentioned, it opens the way for a renewed international carbon market that, rising from the ashes of the Kyoto Protocol's flexible mechanisms, will likely be structured to perform better. The perspective of a "Carbon Market 2.0", as many called it, had been welcomed by those that consider it as an opportunity to enhance mitigation efforts, reinforce existing carbon mechanisms and spur private investments (Widge, 2015).

It is difficult to understand what kind of cooperation could emerge and how the new framework will relate with the flexibility mechanisms under the current Kyoto's regime (the Clean Developed Mechanism and Joint Implementation) but the language seems to support at least the linking of national emission trading systems among those countries that would like to. It is likely that the overall structure coming out from the implementation of the Article 6 would be simpler and less structured than the Kyoto Protocol's mechanisms in order to guarantee a greater flexibility for heterogeneous instruments to cooperate. However, the practical operationalization of this option will pose future negotiating challenges especially related to the environmental integrity, double counting and transparency provisions (Marcu, 2016). These issues are indeed often raised by some Parties to block the inclusion of any provision that refers to "markets" within the Paris Agreement. The fact that NDCs allow countries to adopt different climate policy tools and targets implies a rethinking of linkage mechanisms' functioning and therefore of the accounting rules for emissions transfers. The task is, however, not unfeasible (Mehling, et al., 2017)

Overall, even with a solid infrastructure, demand of transferable mitigation outcomes as we conceive them now will likely be scarce, since only about a handful of the about 90 countries that opened to the use of carbon markets in their (I)NDCs will likely to be buyers (EDF & IETA, 2016). For this reason, the possibility to involve also transfers to or from non-State actors will likely emerge as a new opportunity to be discussed. In the near term, these uncertainties along with the lack of details about the

future of old mechanisms will barely send a strong signal to businesses looking for market opportunities.

Adaptation: advancing towards parity?

By placing a goal on adaptation, the Paris Agreement fixes the intrinsic disequilibrium of the 1992 Convention, which mentions only the stabilization of GHG in the atmosphere as its ultimate objective. The Article 5 somehow brought to the long awaited "political parity" between adaptation and mitigation. This was achieved by setting a long term adaptation goal besides that on mitigation, and by outlining a similar cycle of action for adaptation communications and NDCs. The language employed, however, is substantially less stringent, although this could signal an attempt not to place excessive reporting burdens on developing countries. For instance, the submission and the periodical update of AC are not binding, and other prescriptions are softened by adding the wording "as appropriate" to the stated obligation.

Yet, the main criticality regards the way progress towards the global qualitative goal on adaptation will be assessed through the global stocktake. The decision accompanying the agreement is silent about the development of methodologies or indicators to this aim. Some proposals had been advanced on the way to Paris. But further discussion will be needed to understand how the different individual adaptation efforts will be assessed towards the achievement of the collective goal.

Mobilizing Climate Finance

Finance is at the same time one of the three key objectives defined by the agreement, a crucial component for the practical implementation of future contributions and an important element of innovation of the new architecture.

Developed countries pledged to continue to provide monetary support to developing countries starting from their 2020 commitment of USD 100 billion per year and increasing it in the next years. The scale of financial resources required to implement developing countries' national obligations appears to be much larger, though.

In fact, total financial costs declared by (mostly) developing countries to implement their INDCs amount to around USD 3,500 billion over the period 2015-2030, of which around USD 500 billion to explicitly come from international donors. Given that not all

countries specified their financial needs, the overall picture can be also bigger than these estimates.

As for the money the developed countries need to mobilize, a joint study by the Organization for Economic Cooperation and Development (OECD) and the Climate Policy Initiative, shows that in 2014 they were able to provide 61.8 billion dollars to developing countries, 70% of which came from public funds. Even though still far from the figures required, it is worth noting that the number has grown in recent years, because of both the increasing commitment of governments and improvements in transparency and reporting systems.

Indeed, besides the clear inconsistency between the resources made available and the level required, the credibility of the Paris' climate finance framework will depend on common procedures and standards to account, track and assess financial transfers and to achieve the promised equal balance between mitigation and adaptation. These elements are still a blind spot and their determination represent both a challenge and an opportunity in the next years.

Thinking in terms of opportunities for future investments, the objective to provide finance to support the low-carbon transformation is likely to send a positive signal to investors as well as to push government to redirect their monetary flows towards climate-proof actions. At the same way, the minimum threshold to provide USD 100 billion/ year and even more from 2025 can give stakeholders a certain predictability on the amount that will be mobilized. Since the agreement, however, does not really address specific measures aimed at helping climate finance mobilization or redirection from dirty to green activities, it is unlikely to produce an immediate effect on the markets, which will rather depend more on the future implementation of NDCs and the overall credibility of the framework.

Future steps

The Paris Agreement was opened for signature on April 22nd 2016, during a day-long special celebration organized by Secretary General Ban Ki-moon at the UN headquarters in New York. The vast majority of UNFCCC Parties (175) signed the agreement on that day, including all major emitters like the United States, China, the European Union (EU), Russia, India, and Japan. Most of them started to deposit their instruments of ratification on that day. Thanks to an unusual smooth ratification

process, the Paris Agreement entered into force on November 4th 2016. The ratification represents certainly an important achievement even though still an initial step to ensure that the Paris Agreement will spread its effects.

Only a few months after the Paris Agreement entered into force, the newly-elected U.S. President Donald Trump announced the intention to withdraw from (and renegotiate) the climate deal. Motivated by domestic economic reasons and the perception of being part of an unbalanced agreement, this decision represents a threat to the accomplishment of the global target. Beyond the primary role of the United States in terms of global emissions, the announcement also raises further worries about other countries' potential negative reaction and consequent additional defections, especially from important players like China, whose strategy was closely related to that of the United States.

Conclusions

Overall, the Paris Agreement represents a crucial step in the history of global climate action. Closing more than two decades of negotiations, the deal signed in the French capital managed to find a common language to have both developed and developing countries on board. One of the main differences with its predecessor, the Kyoto Protocol, relies, indeed, on the greater effort that the Paris Agreement put in building a solid, transparent and flexible process able to engage countries in the long-term rather than focusing on targets.

Although the lack of a strong language on specific mitigation obligations may not seem such a strong signal, provisions on mitigation somehow formalize the bottom-up approach that already emerged well before the conference and that was launched in Cancun in 2010. The final agreement represents indeed a trade-off between the need to increase participation to international climate policy action and the urgency of agreeing on a common long-term policy commitment. With 190 countries that have already submitted an *Intended* Nationally Determined Contribution, the Paris Agreement shows a clear direction, where all Parties are required to play their part in front of the others. Importantly, it also sends a strong signal to the private sector by telling business and investors that the path towards a low carbon and resilient society is the only to be taken. The role of non-State actors appears even more crucial now that one of the major players threatens to withdraw from the agreement.

Nevertheless, a careful reading of the adopted text reveals that the definition of pending details will be of paramount importance for safeguarding the ambition and the credibility of the overall framework. This task is assigned to the newly created Working Group on the Paris Agreement (APA), who started meeting in Bonn in May 2016.

Yet technical work cannot replace political will. The momentum built in Paris and confirmed in New York will be key in determining the effective implementation of the agreement. This is especially true when considering the institutional architecture, based on voluntary contributions framed in legally binding procedures, and its compliance system relying on shared awareness and peer pressure. National governments' commitments and international institutions' oversight will be decisive in keeping the system on track in delivering an effective, consistent and fair global response to climate change.

Acknowledgments

We are grateful to Paola Vesco for her useful help. The research leading to these results has received funding from the Italian Ministry of Education, University and Research and the Italian Ministry of Environment, Land and Sea under the GEMINA project. The usual disclaimer applies.

Notes

A previous version of this essay was published in *Economics and Policy of Energy and Environment,* 2015, vol. 2015/3, issue 3, pp. 5-17. It is coauthored with Calliari Elisa and D'Aprile Aurora.

References

Climate Action Tracker, 2016. Tracking INDCs. [Online] Available at: http://climateactiontracker.org/indcs.html [Accessed 21 march 2016].

Climate Interactive (2015), *Climate Scoreboard*, www.climateinteractive.org/tools/scoreboard/

Environmental Defense Fund (EDF) and the International Emissions Trading Association (IETA) (2015), *Carbon Pricing: The Paris Agreement's Key Ingredient*, April 2016. [Online] Available at http://www.ieta.org/resources/Resources/Reports/Carbon_Pricing_The_Paris_Agreements_Key_Ingredient.pdf

IEA, 2015. Energy and Climate Change: World Energy Outlook Special Report, International Energy Agency, Paris [Online] Available at https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

Marcu, A., 2016. "Carbon Market Provisions in the Paris Agreement (Article 6)", CEPS Special Report No. 128 /January 2016, Brussels.

Mehling, M.A., Metcalf, G.E. & Stavins, R. N., 2017. *Linking Heterogeneous Climate Policies (Consistent with the Paris Agreement)*, Discussion Paper ES 17-6, Harvard Project on Climate Agreements.

OECD (2015), "Climate finance in 2013-14 and the USD 100 billion goal", a report by the Organisation for Economic Co-operation and Development (OECD) in collaboration

with Climate Policy Initiative (CPI). [Online] Available at http://www.oecd.org/environment/cc/OECD-CPI-Climate-Finance-Report.pdf

Ray, S. et al. (2015). *India's Intended Nationally Determined Contributions Renewable Energy and the Pathway to Paris.* CEEW Policy Brief.

UNEP, 2015. The Emissions Gap Report 2015, Executive Summary.

UNFCCC, 2011. *Decision 1/CP.17 - Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action*. FCCC/CP/2011/9/Add.1. Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011, Addendum.

UNFCCC, 2015. *Adoption of the Paris Agreement, Paris: UNFCCC Conference of the Parties*. Twenty-first session Paris, 30 Nov. to 11 Dec. 2015.

UNFCCC, 2016. *Synthesis report on the aggregate effect of the intended nationally determined contributions: an update - Synthesis report by the secretariat*.

Widge V., 2015, *Carbon markets in the Paris Agreement - an early holiday gift*. World Bank Blog. [Online] Available at at http://blogs.worldbank.org/climatechange/carbon-markets-paris-agreement-early-holiday-gift

WRI, 2016. CAIT, CAIT Climate Data Explorer, INDC Dashboard. [Online] Available at: http://cait.wri.org/indc/ [Accessed 30 April 2016].

From the Right to Development to the "Common but Differentiated Responsibilities" and beyond: evolution of the equity principle in the climate change regime

Introduction

The Right to Development (RtD) was introduced in the 1970s as a *third generation right*, along with the right to peace and the right to a clean environment. At a practical level, however, the RtD is relatively new to the international human rights framework: it was included in 1981 in the African Charter on Human and Peoples' Rights and only in 1986, the Declaration on the Right to Development was adopted by the United Nations General Assembly (UNGA), which proclaimed it as a human right (United Nations, 1986). Subsequently, the RtD was also referred as an inalienable human right in the Vienna Declaration of 1993 and has been mentioned in numerous other outcomes of global summits and conferences (United Nations, 1993).

Article 1.1 of the Declaration on the Right to Development states that:

"The right to development is an inalienable human right by virtue of which every human person and all peoples are entitled to participate in, contribute to, and enjoy economic, social, cultural and political development, in which all human rights and fundamental freedoms can be fully realized."

According to this definition, the RtD aims at establishing an international framework in which human rights can be fully realized through a process of development everyone can participate and contribute to as well as benefit from. In addition, the Declaration requires that considerations of equity and justice should determine the whole development process and the opportunity of access to basic resources, education, health services, food, housing, employment as well as the distribution of income. Therefore, the Declaration clearly indicates that the primary responsibility for implementing the RtD belongs to States. To this purpose, all nations

are asked to cooperate internationally and work nationally to ensure that this comprehensive process is undertaken without discrimination, and that all people may be fully and equally involved in it (United Nations, 2011).

Due to its multidimensional nature, the core elements of the RtD became also part of the international discourses on climate change action and sustainable development, especially in terms of respect for all human rights, equity and international cooperation.

The Rio Declaration on Environment and Development, which was agreed at the 1992 Earth Summit in Rio de Janeiro, affirmed the RtD: in identifying the three mutually reinforcing pillars of sustainable development as economic prosperity, social equity and environmental protection, the principle 3 states that "*The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations*" (United Nations General Assembly, 1992). Two years later, in 1994, the United Nation Framework Convention on Climate Change (UNFCCC, 1992), in its article 3(4) recalls the RtD as both a right and a duty of states to "*promote sustainable development*". Noteworthy, the economic dimension of the RtD in this case is complemented by the qualification "*sustainable*" and closely bound to the integration principle which, in the same provision affirms that policies and measures for the Convention's implementation should "*be integrated with national development programmes, taking into account that economic development is essential for adopting measures to address climate change*". As noted by Pallemaerts et al. (2006), the intentional ambiguity of the text leads it to be interpreted in two ways: is it the economy which must determine the environmental policies, or vice versa?

Although its broad basis and an overall moral support, the RtD has not been warmly welcomed in practice and its effective enactment is affected by grave deficiencies (Sengupta, et al., 2005). This essay aims at exploring the sources of this ambiguity and the implications for the climate change and sustainability spheres. The next paragraphs address respectively i) the inherent vagueness of the RtD starting from the lack of political consensus on its status and the barriers to the practical implementation, ii) the integration and different interpretations of the RtD within the UNFCCC context, iii) the evolution of the CBDR-RC principle from the Kyoto Protocol to the Paris Agreement, iv) some conclusions and steps forward.

The Right to Development: an inherent ambiguity?

The all-comprising and not very concise definition of the RtD has led to different interpretations especially opposing developed and developing countries' views.

A historical element of disagreement relates to the definition and scope of the "right to development", the duty it entails, and the subjects to which this right attaches (Kirchmeier 2006, Rajamani 2010 and Sengupta 2013). In particular, it originates from the fact that the RtD cannot be identified with a natural right, which on the contrary, is clearly and unambiguously conceptualized as universal, held equally by all, and therefore inherent to humans and not the product of social cooperation (Alston, 1980). The formulation of the article 1 of the Declaration, which states that "*every human person and all peoples*" are entitled to the human RtD, indeed, led some, especially developed countries, to interpret this dualistic nature as a synthesis right which encompasses all other rights, and therefore not to be regarded as a human right. The United States, in particular, consistently rejected this notion so much that in 1986, the country voted against the adoption of the Declaration on the Right to Development, while a handle of European nations abstained. Moreover, at the Rio Summit, in 1992, the United States introduced an interpretative statement to Principle 3, which points out that, by joining consensus on the Rio Declaration, the country does not "*change its long-standing opposition to the so-called 'right to development'. Development is not a right. On the contrary, development is a goal we all hold, which depends for its realization in large part on the promotion and protection of the human rights set out in the Universal Declaration of Human Rights*."[3] Although much of this debate has been mainly overcome by the inclusion of the RtD among the inalienable human rights in the Vienna Declaration in 1993, diverging views still make the creation of a framework to realize the obligations relating to that right a politically contested issue (Kirchmeier, 2006 and Sengupta, 2013).

In particular, a crucial issue is related to the justiciability of the RtD. Some legal scholars argue that, since the RtD is not legally enforceable – i.e. the entitlement to the right cannot be sanctioned by a legal authority, such as the State - it cannot be regarded as human rights (Kirchmeier, 2006). It is true that, differently from other human rights, that are codified in international treaties or covenants and ratified by a

[3] See United Nations Conference on Environment and Development, 'Report of the United Nations Conference on Environment and Development' (1992) A/CONF 151/26 (vol IV), 20. See also (1992) A/CONF 151/26/Rev 1 (vol II) Ch III.

large number of States and supplemented by protocols allowing for individual complaints, the Declaration does not have that status and therefore cannot be enforced in a legal system. As a consequence, the positive actions that are necessary may often make the RtD – as other economic and social rights - very difficult to precisely identify the obligations of particular duty holders to make them legally liable to litigation. According to Sengupta (2013), however, these features do not diminish the responsibility of States, nationally or internationally, nor that of individuals and international agencies, to realize the RtD. The main challenge, instead, is to find alternative mechanisms to monitor or exercise surveillance over States and agencies of the international community to ensure that they are complying with their commitment to realize the RtD (Sengupta, 2013).

Strictly connected to this aspect is the monitoring of implementation. Monitoring process implies the use of indicators and the capability to collect and compare them. In the absence of a consensus on what can be considered in RtD measures, indicators of availability have been until now mainly derived from the conventionally used socioeconomic indicators. In particular, the eradication of poverty – the worst form of deprivation of human rights – and the protection of vulnerable groups have been proposed as a possible measure to capture the main dimensions of the RtD (Sengupta, 2013). A further obstacle, however, concerns the availability of resources – including financial, physical and institutional, both at the national and the international level – the lack of which would constrain the speed and coverage of the realization of the RtD. The importance of resource constraints is explicitly recognized by current human rights instruments, including the International Covenant on Economic, Social and Cultural Rights and the Declaration on the Right to Development (United Nations, 1986). Although for some countries the resource constraints may not be insurmountable, it may be necessary to prioritize among different rights. But such prioritization needs not to contradict the principle that "*all human rights are indivisible, interdependent, interrelated and of equal importance for human dignity*" as stated by the Vienna Declaration (United Nations, 1993). This means that there cannot be any trade-off between rights and the violation of one right cannot be compensated by the improved realization of any other right. This notwithstanding, the question would arise of how to decide on the relative preference between rights. Different approaches have been proposed, as for example defining a set of "minimum core obligations" or "basic

rights" or preferred incremental changes in the realization of the development process (Sengupta, 2013). It should be noted also the high level of interdependency, which could imply that the realization of one right – for example the right to health – depends on the level of realization of other rights - such as the rights to food, housing, liberty and personal security. Overall, the problem of resource scarcity has been claimed no to be used as a pretext for avoiding action (Sengupta, 2013). In this context, growth becomes both a means and an end in the process of development. Therefore, programs for realizing the RtD should aim at expanding resources through a process of sustainable growth consistent with human rights standards. This concept is very important since it relates to the efficient and less wasteful use of existing resources in order to increase the supply of financial resources and have a much greater impact on realizing the RtD.

A final important dimension that is crucially linked to the resource debate is the cooperation duties that the RtD entails. As mentioned above, the Declaration on the Right to Development explicitly requires States to "*cooperate in ensuring development and eliminating obstacles to development*" (United Nations, 1986 art. 3.3). As summarized by the Office of the High Commissioner for Human Rights (OHCHR), the Declaration overall fosters friendly relations between States, international solidarity, cooperation and assistance in areas of concern to developing countries, including technology transfer, access to essential medicines, debt sustainability, development aid, international trade and policy space in decision-making (United Nations, 2011). Since the beginning, however, the debate focused around two main issues: the transfer of resources to developing countries and their favorable treatment in international trade and finance (Sengupta, et al., 2005). This led developed countries to be very reluctant in fully engaging in such an issue, due to the fear that the RtD may be interpreted as a 'right to development assistance' (Kirchmeier, 2006). The most important tool to realize the international cooperation in this field is, indeed, the Official Development Assistance (ODA), that allows donors to directly help developing nations. It is important to recall here the repeated (voluntary) commitment made 45 years ago by the world's governments (with the exception of United States and Switzerland) to flow 0.7% of rich-countries gross national product (GNP) through Official Development Assistance. Since only few countries honored this commitment so far, it should not come as a surprise that raising ODA to the minimum target dominated much of the reporting and policy advocacy also within the Millennium Development

Goals and in particular, Goal 8 which aimed at building a Global Partnership for Development by 2015 in some relevant policy areas such as trade, aid, debt relief and technology transfer (Kirchmeier, 2006).

The international climate change debate: from the right to development to the right to emit?

A complex and deep link exists between the RtD and climate changes. On the one side, the disruptive effects of unmitigated climate changes are likely to undermine the realization of the RtD – along with a broad range of internationally recognized human rights – on the other, the action against climate change is often felt to be a danger to the fulfillment of this right, especially by developing countries (Kartha et al. 2012 and Rajamani, 2010). The bottom line here is that the path to 'development' – to water and food security, improved health care and education, secure livelihoods – as experienced so far by the industrialized world, involves expanding access to energy services, and, consequently, a seemingly inevitable use of natural resources and fossil fuels leading to an increase in carbon emissions. As a consequence, many emerging and developing economies wish to follow the same proven route to development (Kartha et al. 2012). But the effect is causal and mutually reinforcing. Indeed, as the vast literature on climate change vulnerability shows (IPCC, 2014), the worst impacts of climate change are likely to be experienced by individuals and groups, whose development is still to be fully realized and that lack the capacity to understand or prepare for the effects of climate change.

Against this background, the RtD entered the discussion within the UNFCCC, which, as mentioned above, does not explicitly endorse the 'right' to development, but it recognizes the central role that development plays in the climate change regime. It is important to mention here that, although the principle gained particular prominence in the context of climate negotiations, it is also relevant for other conflicts of interest along the North-South divide of international politics (Rajamani, 2010). In particular, the Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) became a cardinal notion, introduced to formally integrate environment and development internationally and as a way to broaden cooperation by equitably sharing commitments among countries (Pauw, et al., 2014). Within the UNFCCC context, it establishes unequivocally the common responsibility of States for the protection of the

global environment at the same time recognizing that broad distinctions between them exist with respect to the application of the Framework obligations.

As described by Rajamani (2010), however, the core content of the CBDR-RC principle as well as the nature of the obligation it entails are deeply contested, both in the literature and negotiations. Two main opposite interpretations can be distinguished: the first sees the CBDR-RC principle building upon the existing differences in the level of economic development, whereas according to the second, the CBDR-RC principle is based on differing contributions to global environmental degradation. As for the nature of the obligation, some argue that it is a mandatory principle while others, and the United States in particular, contend that it can be only discretionary (Rajamani, 2010, Pauw, et al., 2014).

Notwithstanding this disagreement, the CBDR-RC played a key role in enabling negotiators to agree on an international legal framework for climate action in the 1990s. The different level of commitments between Annex I and Non-Annex I countries agreed under the Convention and then reinforced in the Kyoto Protocol are the main example of the application of a differential treatment between countries having different levels of economic welfare – measured in gross domestic product (GDP) per capita in the immediate wake of the collapse of the Soviet Union. Although its comprehensive formulation, the principle has been mostly discussed in relation to the reduction of greenhouse gas (GHG) emissions, and indirectly to some related topic such as financial and technological support, flexibility mechanisms (Orellana, 2013). Moreover, the Framework Convention identifies sets of countries that are traditionally considered vulnerable and therefore deserve a special treatment both in terms of duties and support. Indeed, decisions under the UNFCCC indicate a tendency to circumvent the issue when related to other fields. As the recent debate shows, Annex I Parties refuse any explicit mention in relation to the adaptation provisions, as it would correspond to acknowledging historical responsibility for emissions and, hence, liability for corresponding adaptation needs and compensating for loss and damage.

By means of the CBDR-RC, however, the RtD has been often equated to the right to emit (Rajamani, 2010, Orellana, 2013 and Pauw, et al., 2014). In particular, most developing countries support a strict interpretation of principle and therefore of the Annex I/non Annex I dichotomy. In practice, the lack of a quantified mitigation target for non-Annex I Parties, implicitly means that emissions of developing countries are

allowed to grow in accordance with their development needs. In order to meet pressing development imperatives, they have, therefore, used the principle to largely resist any quantifiable limitations on emissions (Keohane, 2016). From their perspective, forfeiting the CBDR-RC would be tantamount to compromising their right to development. However, the rise of emerging economies has made it much harder than ever to identify how the responsibilities of states differentiate, increasingly bringing into question the CBDR-RC compromise. (Pauw, et al., 2014). In fact, since the UNFCCC was adopted in 1992, almost no progress has been made to better include the recent differences emerging among developing countries themselves.

The CBDR-RC continues to be a recurrent issue in recent debate aimed both at agreeing a second commitment period under the Kyoto Protocol and preparing the ground for Paris global deal, as envisioned under the UNFCCC "Durban Platform". It is important to mention here that recent attempts to include an equity-based right to development in the climate negotiations debate as well as on the sidelines of it, saw several proposals. The right to an 'equitable sharing of atmospheric space' (as proposed by the government of India in 2009),[4] the distinction between survival and luxury emissions, the Greenhouse Development Rights framework (based on the right of all people to reach a dignified level of sustainable human development),[5] (Baer et al., 2010) and the Contraction and Convergence proposal[6] (based on per capita CO2 emission entitlements) are only few of them (Pauw, et al., 2014). However, the reluctance of emerging economies in emancipating from their status of non-Annex I countries has raised the stakes regarding the interpretation and, ultimately, blocked any evolution in the application of the CBDR-RC and, more broadly the RtD.

The evolution of the CBDR principle from Kyoto to Paris

Since the Kyoto Protocol's adoption, many things as well as the world itself, have changed. The Durban Platform, which launched the process for the Paris Agreement's adoption, does not contain any mention to the CBDR-RC principle, primarily because of interpretation divergences among the UNFCCC Parties. The two subsequent Doha and Warsaw decisions have only a general reference to it. In contrast, the Lima Call to Action, adopted in 2014, reaffirms the principle of "*common but differentiated*

[4] http://www.envfor.nic.in/mef/UNFCCC_final.pdf
[5] http://gdrights.org/
[6] As proposed by BASIC Experts http://www.gci.org.uk/contconv/cc.html#intro

responsibilities and respective capabilities", that is however complemented by the words "*in light of different national circumstances*" (Rajamani 2015), reiterating the importance of consider each country's circumstances. However, the specific reference to the language characterizing differentiation based on Annex I and non-Annex I countries disappeared. This development is also a consequence of the historical changes in the post-Kyoto period. Indeed, while the Kyoto Protocol reflects the world structure of the 90's, the static categorization of countries listed in the UNFCCC Annexes no longer represents the current socio-economic landscape. In fact, some of those that were considered developing countries, such as China, India, Brazil and Indonesia, are among the major world economies nowadays, with a consequent growing level emissions. In 2007, China definitively overtook the US in being the top world emitter. In 2012 the Asian country accounted for 29% of global annual emissions, while the US had a share of 16% and the EU close to 11% of the world's total (Zaccai & Lugen, 2016). In addition, aggregate emissions of non-Annex I countries increased by 223% in the period 1990-2008, whereas the emissions of Annex I countries roughly remained the same. Despite this, under the Kyoto Protocol and its second commitment period, China is exempted from undertaking any abatement commitment. The demarcation line between Annex I and non-Annex I countries seems inappropriate for the time being, and consequently also to shape future climate and burden sharing perspectives, as old industrialized Parties' mitigation efforts are no longer sufficient to avoid climate change impacts (Pauw 2014; van Renssen 2015). In this vein, during the last negotiations, it was evident that, to try keeping the increase in atmospheric temperature within the 2 degrees threshold above the pre-industrial levels, a global commitment from all countries would have been needed. On the other hand, many developed countries had affirmed that they would have not joined a new climate agreement without developing countries' participation, especially calling for major emerging economies' commitment.

The CBDR principle in the Paris Agreement

In the process ahead of the COP21 negotiations, UNFCCC Parties agreed that the new climate deal should have reflected the differences in countries' conditions and responsibilities, but the single positions on the matter were extremely polarized. In particular, disagreement emerged especially on how the new deal should have tackled differentiation to establish respective obligations under mitigation, adaptation, finance,

technology transfer, capacity building and transparency. Developing countries, led primarily by China and India, were in favor of the strict observance of Convention's principles, including the CBDR-RC. They strongly opposed an agreement with "symmetric" provisions for all the participants. On the other side, the EU supported the application of Framework Convention criteria in a contemporary manner, according to evolving realities. Similarly, the US, although formally embracing the CBDR-RC ideal, called for a reinterpretation that did not contemplate the annexes traditional division. Overall, developed countries supported the idea that the Nationally Determined Contribution (NDCs), as an autonomously determined tool, already represented a sort of differentiation, and no other "asymmetric" measures would have been needed.

With the adoption of the Paris Agreement a step forward has been finally taken with regard to the Kyoto's effort-sharing approach. In fact, representing a crucial compromise among Parties' position, the final text addresses both differentiation and the CBDR-RC principle in a different way compared to the Kyoto Protocol.

The first thing that stands out is that, contrary to the Kyoto Protocol, the Paris Agreement did not contain even a single reference to historical responsibilities or Annex and non-Annex I countries. Overall, it recalls the CBDR-RC principle in many features, even though it is not enunciated in a binding or defining specific way. Looking at the text, the CBDR-RC principle appears four times, each one followed by the fact that it should be considered "*in light of different national circumstances*" (UNFCCC, 2015). The first (in the Preamble) and second (in Article 2) times it appears, the CBDR-RC is linked to the equity ideal, as complementary guiding principles of the Convention under which the agreement is stipulated. Then, in article 4, the Agreement reiterates again the principle twice: as a marking out for new, ensuing and progressive NDCs for countries, embodying the highest possible ambition, and lastly, as a guide for long-term, low-emission GHG development strategies to communicate. In addition, the Paris Agreement remains unambiguously linked with equity as a criterion to implement a fair deal among the Parties. Article 4 explicitly affirms that long-term emission stabilization objectives have to be implemented "*on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty*" (UNFCCC, 2015). Besides, the Right to Development is mentioned in the Preamble as a principle to consider when taking action against climate change.

In Article 4.4, the agreement introduces an attempt to formally differentiate between the participants by stating that "*developed country Parties should continue taking the lead*" through "*economy-wide absolute emission reduction targets*", whereas "*developing country Parties*" are only "*encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances*" (UNFCCC, 2015). In addition, the provisions related to developing countries often consider their "*special circumstances*", especially referring to the Least Developed Countries or Small Island States (Climate Council, 2015; Climate Focus, 2015; UNFCCC, 2015). However, in practical terms the differentiation system remains vague. In the Agreement text, developed and developing countries are mentioned many times, but a distinctive definition of which countries should be included in the two categories is not available.

Through the NDCs all Parties are called to contribute to the agreement's objectives, even though they are allowed to voluntarily define their contents, de facto enshrining the CBDR-RC principle through a self-differentiation. Accordingly, the NDCs provide the linchpin on how each government envisions the integration between its national development strategies and the protection of the global climate system. The NDCs submission process is therefore judged by many as an implicit differentiation, as they represents a self-made proposal containing what is considered a fair contribution for the country, in the context of its possibilities, capabilities and priorities (Meinshausen et al, 2015).

Another distinctive aspect linked to the CBDR-RC is the inequality implied in climate change consequences and adaptive capacity. Developing countries are expected to be the most affected by climate change impacts, while they have the least potentialities to afford the adaptation costs. However, although the "loss and damage", which was one of the most contentious issues, managed to enter the final text of the Paris Agreement, the article 8 does not provide any basis for "liability or compensation", which implies that neither monetary compensation, nor responsibility can be attributed to industrialized countries. The Decision Adopting the Paris Agreement introduces, however, the mandate for developed countries to provide "*USD 100 billion per year taking into account the needs and priorities of developing countries*", while article 9 of the agreement reiterates the developed countries' pledge to mobilize climate finance. These funds, expected to bankroll both mitigation and

adaptation actions in developing countries, represents a credibility test for developed countries in showing their commitment to the CBDR-RC principle.

The way forward

After years of debate the RtD still represents a controversial concept, whose inherent ambiguity makes its implementation and advancement a challenging task.

In relation to sustainability and climate change issues, its operationalization, in particular through the CBDR-RC principle, provided some important steps towards the integration of development beyond the economic sphere. However, despite its widely recognized importance, the CBDR-RC in recent times proved to act as a major obstacle in negotiating an international new climate agreement. The original dichotomous differentiation between Annex I and non-Annex parties no longer reflects current political realities but any move forward was complicated by the persistent vagueness and uncertainties as well as by the multiplication of state groups and country coalitions that raised the stakes regarding the interpretation and, ultimately, the practical implementation of CBDR-RC (Rajamani, 2010 and Pauw, et al., 2014).

Recognizing equal dignity to all contributions, the Paris Agreement overcome the traditional differentiation between Annex I and non-Annex I countries' commitments, opening the door to a flexible structure, where developed and developing countries cooperate together in the fight to climate change. However, the new language on differentiation system remains quite vague. The demarcation line between developed and developing countries is not clear, as the agreement overall lacks a distinctive definition of which countries should be included in the two categories. This ambiguity poses the basis for potential future challenges. Among these, how to align the "Nationally Determined Contributions" (NDCs) – which includes individual countries' view of what their fair contribution should be, in accordance with national possibilities, capabilities and priorities – with the Paris Agreement's temperature long-term objectives will emerge as a crucial issue.

Beyond the UNFCCC context, the post 2015 Agenda, and the 17 Sustainable Development Goals (SDGs) adopted just a few months after Paris, offer to the international development community a new opportunity to boost policy coherence between development promotion, human rights commitments and environmental protection. Main objective of the SDGs is to continue fighting against extreme poverty

but at the same time ensuring more equitable development and environmental sustainability. However, some of the main flaws characterizing the RtD and CBDR-RC can still fuel diverging views among countries. For this reason a crucial element for the success of the SDGs will be a clear delineation of indicators as well as commonly agreed definitions to enable comparison that will of course depend also on the availability of data and states' capacity to measure them (ICSU, ISSC, 2015).

References

Alston, P. 1980. *The right to development at the international level.* Work- shop, The Hague, 1980. R.J. Dupuy (Eds), 1980.

Baer P., Athanasiou T., Kartha S., 2010. The Greenhouse Development Rights Framework: The right to development in a climate constrained world. In: Voss M. (eds) Der Klimawandel. VS Verlag für Sozialwissenschaften

Climate Council, 2015. "Paris COP21: Key Issues for the New Climate Agreement", Climate Council Briefing Paper, 2015.

Climate Focus, 2015. "The Paris Agreement Summary", Climate Focus Client Brief on the Paris Agreement III, December 2015.

ICSU, ISSC, 2015. *Review of Targets for the Sustainable Development Goals: The Science Perspective.* Paris : International Council for Science (ICSU), 2015.

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A:Global and Sectoral Aspects*. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

Kartha S., Athanasiou T., and Baer P., 2012. "The North-South divide, equity and development– The need for trustbuilding for emergency mobilisation", in Hällström N.(ed.), 2012. Climate, Development and Equity, What Next Volume III, Development Dialogue, September 2012 |

Kirchmeier, F. 2006. *The Right to Development - where do we stand? State of the debate on the Right to Development. Occasional Papers No. 23/July 2006.* s.l. : Friedrich-Ebert-Stiftung (FES), 2006.

Keohane, R., 2016. *Keohane on climate: what price equity and justice?.* [Online] Available at: http://www.climatechangenews.com/2016/09/06/keohane-on-climate-what-price-equity-and-justice/ [Accessed 06 06 2017].

McManus K. 2009. "The principle of 'common but differentiated responsibility' and the UNFCCC", Climatico Special Features, November 2009.

Meinshausen M., Jeffery L., Guetschow J., Robiou du Pont J., Rogelj J., Schaeffer M., Höhne N., den Elzen M., Oberthür S., and Meinshausen N., 2015. "National post-2020 greenhouse gas targets and diversity-aware leadership", in *Nature Climate Change*, Macmillan Publishers Limited , vol. 5, October 2015. DOI: 10.1038/NCLIMATE2826

Orellana, M. 2013. Climate change, sustainable development and the clean development mechanism. *Realizing the Right to Development. Essays in Commemoration of 25 Years of the United Nations Declaration on the Right to Development.* s.l. : United Nations Publication, 2013.

Pallemaerts, M. and Williams, R. 2006. Climate change: the international and European policy framework. [book auth.] and Deketelaere K. Peeters M. *EU Climate Change Policy.* Cheltenham, UK • Northampton, MA, USA: Edward Elgar, 2006.

Pauw, P., Bauer, S., Richerzhagen, C., Brandi, C., Schmole, H. 2014. *Different Perspectives on Differentiated Responsibilities. A State-of-the-Art Review of the Notion of Common but Differentiated Responsibilities in International Negotiations. Discussion Paper 6/2014.* Bonn : Deutsches Institut für Entwicklungspolitik, 2014.

Rajamani L. 2015. "Differentiation in a 2015 Climate Agreement", in <Center for Climate and Energy Solutions (C2ES)>, June 2015.

Rajamani, L. 2010. *Rights-Based Perspectives on Climate Change Negotiations.* 3, s.l. : Oxford University Press, 2010, Journal of Environmental Law, Vol. 22, pp. 391-429.

Van Renssen S. 2015. "Getting a fair deal", in *Nature Climate Change*, Macmillan Publishers Limited, vol. 5, June 2015.

Sengupta, A. 2013. Conceptualizing the right to development for the twenty-first century. [book auth.] UNOHCHR. *Realizing the Right to Development. Essays in Commemoration of 25 Years of the United Nations Declaration on the Right to Development.* s.l. : United Nations Publication, 2013.

Sengupta, A., Negi, A. and Basu, M. 2005. *Reflections on the Right to Development.* s.l. : Center for the Development of Human Rights, 2005.

United Nations Framework Convention on Climate Change, 2015. "Adoption of the Paris Agreement", 21st Conference of the Parties, Paris, December 2015.

United Nations, 1986. *Declaration on the Right to Development. A/RES/41/128.* 1986. http://www.un.org/documents/ga/res/41/a41r128.htm.

United Nations, 1992. "United Nations Framework Convention on Climate Change", 1992.

United Nations, 1993. Vienna Declaration and Programme of Action. [Online] 25 June 1993. http://www.ohchr.org/EN/ProfessionalInterest/Pages/Vienna.aspx [Cited: 10 May 2015.]

United Nations, 2011. The Right to Development at a glance.Office of the High Commissioner for Human Rights (OHCHR). [Online] 2011. [Cited: 10 May 2015.] http://www.un.org/en/events/righttodevelopment/pdf/rtd_at_a_glance.pdf.

United Nations General Assembly, 1992. REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT.Rio Declaration on Environment and Development. [Online] 3-14 June 1992. [Cited: 10 May 2015.] http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm.

Vanderheiden S. 2015. "Common but Differentiated Responsibility", in Essential Concepts of Global Environmental Governance, Rutledge, London and New York, pp. 31-34, 2015.

Wang X. 2006. On the Right to Sustainable Development: Foundation in Legal Philosophy and Legislative Proposals. In: *Implementing the Right to Development: The Role of International Law*. Stephen P. Marks, (Eds).

Zaccai E. and Lugen M., 2016. "Common but differentiated responsibilities against the realities of climate change". In: Papaux A., and Zurbuchen S. (eds), 2016. "Philosophy, Law, and the Environmental Crisis", Archiv für Rechts--- und Sozialphilosophie.

Fairness in NDCs: comparing mitigation efforts from an equity perspective

Introduction

The debate for the distribution of collective climate change objectives inevitably raises issues related to ethics and responsibility. Along with efficiency, equity is indeed a key element of an effective international climate policy agreement (Carraro, 2000; Müller, 2001). By involving value judgement and national interests, the matter represents a point of disagreement among countries that has been accompanying the whole UNFCCC process since the beginning of climate negotiations in the 1990s. Although UNFCCC Parties agreed on the Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) as the guiding principle to equitably share commitments, there is no a unique interpretation of how it should implemented practically.

With the introduction of the Nationally Determined Contributions (NDCs) and the new bottom-up approach to the definition of emission reductions launched with the Paris Agreement, the issue gained even more relevance. In its article 2, the Paris Agreement confirms its purpose of implementing the commitments in order "to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (UNFCCC, 2015). However, each country implicitly or explicitly includes an own interpretation of how the burden should be fairly distributed or justifies why the proposed contribution should be considered equitable. Indeed, single countries strongly differ in terms of current and historical emission levels, vulnerability to climate impacts and economic capabilities. These differences are fully reflected in their NDCs. According to the objectives of the Paris Agreement, however, the sum of the self-determined domestic emission reduction contributions needs to be consistent with the emissions pathway required to limit global temperature increase to 2°C by 2100.

Against this background, this essay aims to combine these two aspects (equity and stringency) to assess the mitigation component of the NDCs provided by different countries. It enriches the emerging literature aimed at providing a benchmark for the evaluation of the NDCs mitigation effort including also equity principles, and going beyond a quantitative assessment of the emission required to stay under the 2° C target. More broadly, our findings will be able to inform the UNFCCC negotiating debate within the first facilitative dialogue in 2018, which will be followed by the first global stocktake to take place in 2023.

Implementing equity principles in the climate change debate

The academic literature discussing equity in the context of environmental governance is vast and interdisciplinary, encompassing philosophy, economics, political and social sciences.

Overall, the research community agrees quite unanimously in considering the equity principle essential for the establishment of any global climate change regime and its effective sustenance. Although the inherent complexity and fuzziness of the concept make its operationalization elusive (Aslam, 2002; Fleurbaey, et al., 2014; Howard, et al., 2016) it is recognized that greater cooperation is likely to emerge if the main elements of the climate change regime, including the policy process, implementation decision and outcome, are perceived to be fair (Morrisette & Plantinga, 1991; Kverndokk & Rose, 2008; Winkler & Beaumont, 2010).

Against this background, a consensus emerged on the need to find plausible mechanisms to convert abstract principles into a form to be used in international climate negotiations and that could possibly be easily applicable and transparent (Bretschger & Zue, 2013). In particular, through effort-sharing approaches the costs (and benefits) associated to mitigation actions can be distributed differently across countries without affecting the overall efficiency of the global abatement effort (Edenhofer, et al., 2014). However, in the real world countries have very different views of what can be deemed equitable, being the perspective strongly influenced by single country's self-interest. Some have, indeed, argued that emphasizing equity in climate negotiations can raise a trade-off with efficiency and encourage countries to exploit ethical justifications in order to avoid stringent commitments (Keohane, 2016).

Among the early studies that contributed to the understanding of the issue, Rose (1992) provides a comprehensive overview of various principles for sharing costs and benefits of climate change and discusses their transformation into operational rules for distributing tradeable greenhouse gas emission permits. In particular, the author classifies different equity criteria into three major categories: allocation-based, outcome-based and process-based, which have become the most-commonly used categorizations by the literature on fairness in climate change policy (Rose, 1992). The distinction refers to the different rules applied to decide the initial allocation of emission permits (e.g. proportional to countries, population or wealth), the final outcome of the implementation of the policy instrument (e.g., how the net impact on welfare is shared), or to the process of allocating or trading permits (e.g. stable negotiations process or fair market rules). As noticed by Müller (2001), however, allocating emission quotas and sharing out the burden of climate change actions are different from a moral perspective. If the former includes some assumption on the proportionality, the outcome of the latter can indeed be independent from the origin of the costs and benefits to be distributed (Müller, 2001).

Building on Rose's analysis, many studies have reviewed the alternative equity principles advanced for defining common but differentiated responsibilities, mainly focusing on the impact of different approaches on the distribution of emission allowances at a global or regional level (Ringius, et al., 1999; Clarke, et al., 2014; Robiou du Pont, et al., 2017) or assessing the implications of each principle on social welfare (Cazorla & Toman, 2000; Mattoo & Subramanian, 2012; Rapauch, et al., 2014)

For the purpose of this essay, we focus on recent studies that used equity principles and indicators to analyze the first category, namely the different effort-sharing approaches to define the initial allocation of emissions. It should be noted that academic contributions go hand in hand with the developments in the UNFCCC negotiations. With the objective to analyse one of the novelties in the Kyoto Protocol's architecture, earlier studies mainly framed their research questions in terms of finding an equitable distribution of tradable emission permits, which would be able to provide flexibility and reduce the cost of the collective target's achievement (Rose, 1992; Ott & Sachs, 2000). Conversely, more recent studies largely aim at understanding what would be an ideal fair distribution of future abatement quotas between developed and developing country groups or at comparing the different contributions offered by

national governments in the context of the more recent bottom-up approaches adopted in the post-Kyoto international negotiations (Tavoni, et al., 2013). In this more recent approach, the allocation of emissions is therefore often linked to a carbon budget, which is the area under a GHG emissions trajectory consistent with limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise (Allwood, et al., 2014).

A recent review, conducted by Höhne et al. (2014), recalled also in the IPCC's fifth Assessment report (Clarke, et al., 2014), groups such literature into seven categories. Overall, three basic equity principles emerge as the most frequently applied: i) *equality*, based on individual rights and asserting that each individual has the same right to pollute or to be protected from pollution; ii) *responsibility*, which claims that a greater mitigation effort should be imposed to those who have contributed the most to climate change (polluter pays principle, historical responsibility); iii) *capacity*, suggesting that each country's contribution should be proportional to its ability to bear the costs of mitigation (ability to pay) and should not prevent a legitimate right to development (needs, right to development). A fourth category is represented by the *cost-effectiveness*, which allocates emissions according to mitigation potential or other costs–effectiveness rules (equal marginal abatement costs, triptych approach). The remaining three categories are composed by a mix of the above-mentioned principles. In particular, some authors combine the equality and responsibility principles to compute *equal cumulative per capita emissions* and therefore weigh historical emissions of countries according to their population; others prefer a *responsibility, capability, and need*, which includes the principles of responsibility and capability plus an indicator of the need for sustainable development; finally, the so-called *staged approaches* provide a compromise over several principles that are applied to different countries in various stages (Höhne, et al., 2014). Overall, the authors find that what matters the most is how the equity principles are implemented. Parameters, data, and methods used can lead to very different results also within the same principle category. As a general rule, the group of countries part of the OECD in 1990s are required deep cuts in emissions (either by 1990 and 2010 levels) under all categories, especially for the more stringent stabilization objectives. They would get relatively lower allocation if the emissions are shared according to the *responsibility, capability and need* principle as well as to the *equal per capita cumulative emissions* compared

to other approaches. On the contrary, for the same categories the Asiatic region would be allowed to increase its emissions the most, especially South Asian countries. Africa and Middle East are more favoured respectively by the *equality* and *capability* principles. Allocation for Latin America would be lower than either 1990 or 2010 levels over all effort-sharing categories, but particularly for *equal per capita cumulative emissions* and *equality* categories (Höhne, et al., 2014).

More recent research efforts started to focus on the Nationally Determined Contributions (NDCs) submitted by more than 190 UNFCCC Parties under the Paris Agreement. Besides those focusing on the consistency of the proposed mitigation actions with long-term temperature targets affirmed by the Paris Agreement (Rogelj, et al., 2016), some studies apply the effort-sharing methodologies described above to assess NDCs both in terms of ambitiousness and fairness.

In particular, Peters et al. (2015) allocate remaining emissions to keep global warming below 2 °C by 2100 according to two approaches: an 'equity' approach based on population, and an 'inertia' approach based on current shares of global emissions. By comparing these results with the emissions pathway resulting from the (I)NDCs of the three major emitters (EU, US and China) they find that the EU and US pledges are close to the 2°C target only under the inertia approach. Interestingly, under current Paris Agreement's contributions, the US would exceed its equity quota already in 2020, China in 2027 and the EU in 2032. Clearly an effort sharing based on the equity approach would require more stringent targets (Peters, et al., 2015).

Robiou du Pont et al. (2016) come to very similar conclusions. They quantify the emission allocation which would be consistent with five of the above-mentioned equity principles and compare them to the mitigation component of (I)NDCs submitted by a set of countries and regions. Their methodology aligns aggregate emission allocations with different cost-optimal global emissions scenarios consistent with the 1.5 and 2°C long-term limits. Overall, they show that the aggregate emission reduction tabled by major economies is already 39 percentage points above their averaged allocation under a 2°C scenario with a pre-2020 peak, whereas the aggregated (I)NDCs of the other economies fall short only by 8 percentage points. Focusing on major emitters, China's current target falls outside the range estimated for any of the five equity approaches. The US' and the EU's NDCs are in line with the allocation based on current emission ratios (*staged approach*) and within the range under the *responsibility,*

capability, need principle. Both the EU's and India's mitigation objectives are coherent with the *equality* approach, with the latter also consistent with the equal cumulative per capita (including the '1.5°C pre2020peak' scenario). At regional level, most developing countries' conditional NDCs are more ambitious than the average of the five equity approaches under the 2°C goal, but only Middle East and Africa's aggregated (I)NDCs are consistent with some 1.5° C allocations. According to all equity approaches, except for the *current emission ratios*, OECD countries should further decrease their emissions with respect to what announced in their NDCs. The NDCs of transition economies are not consistent with the *responsibility, capability and need* principle as well as the *current emission ratios*, but they comply with the *equal cumulative per capita emissions* (Robiou du Pont, et al., 2017). In an analogous exercise, Pan et al. (2017) assess the NDCs' mitigation objectives of eight among major emitting countries against six equity principles of effort-sharing. Also in this case, the study highlights the need for most countries to increase the ambition of their 2030 emissions reduction policy. A particularly large emission gap characterizes Russian NDC, which is estimated will be almost the double of its maximum 2030 allowances (available under the *responsibility, capability and need* approach). An exception to the general rule is India, whose conditional target falls within the range of all the selected approaches under a 2°C scenario and the majority of them under a 1.5°C. The upper bound of South Africa's mitigation contribution is consistent with the *responsibility* and the *responsibility, capability and need* principles. (Pan, et al., 2017).

The topic raised a relevant debate also outside the pure academic domain. Interesting analytical contributions are indeed offered also among think tanks and international non-governmental organizations. Among the most relevant contributions, Climate Action Tracker evaluates the coherence of the mitigation plans in the (I)NDCs and a set of indicators including a fair effort sharing allocation budget obtained through the aggregation of estimate ranges coming from pertinent studies (Climate Action Tracker, 2016). In advance for COP21, also Oxfam International (2015) and the French press agency Novethic (2015) released their own indexes of (I)NDCs' fairness, which rate countries' target according an equitable share in line with the 2°C threshold and based on *responsibility* and *capacity* principles. Even though some differences, both studies confirm that the pledges of developed countries and major emitters are far from being a fair contribution, especially for Russia. According to Oxfam (2015),

Japan's effort averages a tenth of a fair distribution, and the (I)NDCs of the EU and the US are approximately a fifth of their estimated fair portion. Brazil represents an exception among emerging economies, covering about two thirds of its equitable part of the global effort, whereas the targets proposed by India is approximately in line with its fair share (Oxfam, 2015). By contrast, in both assessments developing countries' contribution generally corresponds to their fair share or even exceeds it.

Methods

Our assessment consists in a comparison of the cumulative emissions resulting in the period 2015 - 2030 from the implementation of the mitigation targets included in the NDCs against the cumulative emissions for the same period consistent with the path for the <2°C, allocated according three equity indicators. The analysis is conducted at the global level, covering 45 countries and regional aggregations. It is divided into the following steps:

1. The Global Carbon Budget

A crucial element of the analysis is the remaining global carbon budget (CB_G) for the period 2015-2030. As mentioned above, the carbon budget is computed as the area under the emission trajectory in line with a specific temperature objective (Allwood, et al., 2014). As we consider the goal to keep the increase in average temperature below 2°C by 2100, we use the global cumulative emissions for the period 2015-2030 consistent with this objective. GHG emission (excluding land use) estimates are provided by the IPCC AR5 database (Kriegler, et al., 2013). We select the stabilization scenarios consistent with the long-term climate objective of both 450 and 500 ppm CO2-eq projected by seven different energy-economy and integrated assessment models. These scenario are associated with a likely (probability > 70%) achievement of the 2°C target in 2100 (Kriegler, et al., 2013). As the dataset provides emissions in 5-year intervals we interpolate them in order to have annual emissions. The resulting median of world's annual emission levels ($MeGHG_W$) for the years 2015 to 2030 are then summed up to obtain the cumulative emissions that compose the global carbon budget:

$$CB_G = \sum_{t=2015}^{2030} MeGHG_{W,t}$$

2. Equity-based indicators

In order to have a benchmark for the evaluation of the NDCs emission levels, the carbon budget for the period 2015 – 2030 obtained from step 1 is the distributed according to three equity criteria.

In particular, considering the purposes of the article 2 of the Paris Agreement we selected the following equity principles:

a) Historical responsibility (HR);

b) Economic capability (EC);

c) Equal individual rights (ER).

As already mentioned, the methodologies reported in the literature to build these indicators are many and each of them implies different levels of detail. We opt for those that represent feasible options for countries (excluding therefore results implying immediate negative emissions), that are relatively simple to use, and that allow for transparency.

a. Historical responsibility

The proposal to share emissions using an indicator of historical responsibility was firstly advanced by the Brazilian delegation in 1997 during the Kyoto Protocol's consultations (UNFCCC, 1997). Since then, a vast debate has followed both in negotiations and academia to understand what is the best way to operationalize the principle and what are the implications of applying such an approach (Höhne & Blok, 2005). In particular, the assumptions that may influence the results are many and they involve an interpretation of the historical responsibility concept. Among them, the choice of the timeframe is certainly one of the most important along with the source and measure of emissions. As for the first, the debate has been mainly divided between those affirming that countries responsible for climate change should bear the costs of solving the problem (as stated by the Polluter Pays Principle) (UNFCCC, 1997; Neumayer, 2000; Botzen, et al., 2008) and those suggesting that countries should not be hold responsible of something they were unaware of (Grubb, et al., 1992; Grubb, 1995; Singer, 2002; Miller, 2009). The practical consequence is that in the first case

historical responsibilities date back to time of the industrial revolutions in the other case to much later, when the first IPCC's assessment report has been published or at the beginning of the UNFCCC process. It is straightforward that the first approach will put a higher burden to the developed countries whereas in the second the contribution of emerging economies will be more relevant. Another important issue to take in to account are the emission sources, and in particular those from land-use and forestry. Exclusion of these significant CO_2 sources would give less relevance to the contribution of countries where the deforestation rate is high. A further aspect regards how the contribution is expressed: in terms of cumulated emissions, global temperature increase or radiative forcing. In addition to all these aspects, the measure of cumulative emissions is often equalized, according to population or GDP, in order to reflect the size of countries (Neumayer, 2000). Only few studies, however, fully describes how they implement this principle (Matthews, et al., 2014).

For the allocation of the Carbon Budget according to our historical responsibility indicator (CB_{HR}) we use the cumulative emissions 1850 – 2014 of each country or region (r) to first compute a Historical Responsibility Share (HRS). We then use the inverse of this share ($IHRS_r$) to assign each country (r) an inversely proportional share of the global carbon budget (CB_G).

$$HRS = \frac{\sum_{t=1850}^{2014} GHG_{r,t}}{\sum_r \sum_{t=1850}^{2014} GHG_{r,t}}$$

$$IHRS_r = \frac{\frac{1}{HRS_r}}{\sum_r \frac{1}{HRS_r}}$$

$$CB_{HR,r} = IHRS_r \times CB_G$$

Including more recent years to the considered timeframe allow us to take into account also the growing "responsibility" of current emerging economies. Historical emissions are derived from the PRIMAP database, which provides a comprehensive set of national greenhouse gas emission pathways with worldwide coverage (Gütschow, et al., 2017). To compare our estimates with the emission levels deriving from the NDCs

assessment we do not include historical land-use, land cover change and forestry (LULUCF) emissions.

b. *Economic capability*

The intuition behind the economic capability approach derives from the interpretation of the CBDR-RC principle in a way that assigns a larger share of the emission reduction to countries that can afford the cost. On the contrary the poorest, and usually most vulnerable, countries are still free to prioritize their development objectives. Used also in the Kyoto Protocol to differentiate commitments between Annex I and non-Annex I countries, the implementation of this principle usually relies on a quantified measure of wealth or wellbeing, including the Gross Domestic Product (GDP) per capita or the human development index (Jacoby, et al., 2010; Tavoni, et al., 2013; Winkler, et al., 2013).

In order to account for the current most affluent countries to take the lead and bear a higher share of mitigation costs, we use the 2015 national GDP (PPP) per capita (International Monetary Fund, 2017) as a measure to allocate them calculating an inversely proportional share ($IECS_r$) of the global Carbon Budget for the period 2015 – 2030 (CB_G):

$$\mathrm{IECS}_r = \frac{\frac{1}{GDPpc_{r,2015}}}{\sum_r \frac{1}{GDPpc_{r,2015}}}$$

$$CB_{EC,r} = IECS_r \times CB_G$$

c. *Equal individual rights*

The third of our equity indicators is based on the assumption that available allowances should be equally shared among the global population. A key approach is the "Contraction and Convergence" concept. Presented as a global solution to climate change that integrates precaution, equity and efficiency, it was conceived by the Global Commons Institute (GCI) (Meyer, 2000) since the mid 90's in several political fora. This plan suggests that global CO_2 emissions significantly decrease (contraction) up to an agreed target in a given date and each year's emission budget is allocated in order to

achieve equal per capita emissions across world's countries (convergence). The concept has been since then further refined, developing various approaches to distribute the available carbon budget on per capita basis (Singer, 2002; Chakravarty, et al., 2009).

To this purpose, we build on Singer (2002) and estimate an equal per capita emission quota (ER) by using the ratio between the emissions budget for 2015-2030 consistent with the pathway limiting warming to below 2°C by 2100 (CB_G) and the summation of global population in the same period (SSP2 scenario as for O'Neill, et al., 2017).

$$ER = \frac{CB_G}{\sum_{t=2015}^{2030} POP_{r,t}}$$

$$CB_{ERr} = \sum_{t=2015}^{2030} ER \times POP_{r,t}$$

d. Combining the indicators

Finally, the three indicators are combined in order to have a single carbon budget that takes into account all the dimensions considered. Since the object of our analysis is a homogeneous divisible good, such as the global carbon budget, and it is very unlikely that countries agree on one of our candidate equity-based indicators, an acceptable compromise may be to compute a new distribution obtained by aggregating the emission levels associated to our three different indicators.

We use two methods to accomplish this task. The first is a simply averaged combination (CB_A), justified by the fact the CBDR-RC principle does not specify how responsibilities and capabilities should be weighted.

$$CB_{A_r} = \frac{CB_{HR_r} + CB_{EC_r} + CB_{ER_r}}{3}$$

The second aggregation method relies on a population-based voting approach as proposed by Müller (2001) in his global preference score procedure. According to this

method, each country expresses its preference for one of the options (the one which allocates the largest amount of carbon budget emissions) that is then multiplied by the number of people it represents (Müller, 2001). This sort of 'demographic weights' for each candidate option (w_{HR}, w_{EC}, w_{ER}) allows to include also a dimension of representational equity in the definition of the carbon budget (CB_{Dr}).

$$w_{HR} = \frac{\sum POP_{r,HR}}{\sum POP_r}; \quad w_{EC} = \frac{\sum POP_{r,EC}}{\sum POP_r}; \; w_{ER} = \frac{\sum POP_{r,ER}}{\sum POP_r};$$

$$CB_{Dr} = w_{HR} * CB_{HR_r} + w_{EC} * CB_{EC_r} + w_{ER} * CB_{ER_r}$$

We use population data for the year 2015 (World Bank, 2017). The distribution of emissions linked to the equal individual rights approach received the highest scores, with 85% of world population preferences. The *economic capability* and *historical responsibility* follow, chosen by 9 and 7% of global population respectively. The weights are computed accordingly (Table 3).

Table 3: Population-based voting approach: results and assigned weights

Preferred option	HR	EC	ER
Population	500,850,535	621,746,035	6,186,218,054
Weights (w)	0.07	0.09	0.85

3. Emissions reduction in the NDCs

The emission levels 2015-2030 resulting from the NDCs submitted by the selected countries are finally estimated. We run a modelling exercise, using the conditional mitigation objectives stated in the NDCs. The emissions in 2030 are computed by using data from CAIT (WRI 2016) for countries committing to an emission reduction target with respect to a base year, whereas the SSP2 baseline scenario is used as a reference when the reduction is relative to the BAU scenario (O'Neill, et al., 2017).

We perform our modelling exercise with the recursive dynamic Computable General Equilibrium model ICES (Eboli, et al., 2010; Parrado & De Cian, 2014, see Appendix I for further details). Being a General Equilibrium framework, ICES model can provide coherent scenario-specific emission projections, which account for

competitiveness effects in international trade and across sectors in each economy. In addition, the ICES model allows to have a wider country and regional coverage of the analysis[7].

Results

Before delving into a detailed analysis of this essay's outcomes in terms of carbon budgets, it is interesting to briefly look at the indicators used to compute them. Figure 1, presents three pie charts showing the shares, respectively, of historical cumulative emissions (HRS), GDP per capita (ECS) and GHG emissions per capita for the countries subject to our analysis.

It is worth recalling that these are not the shares we directly use to compute the carbon budgets: in the case of *historical responsibility* and *economic capability* we compute an inverse proportion of the respective shares showed in Figure 1, whereas for the equal individual rights, we use the estimated per capita GHG in 2030. This notwithstanding, such figures are useful to have an overview of how the different countries stand with respect to the three metrics at the base of our equity assessment.

As it stands out immediately, the cumulative emissions relative to the period 1850-2014 are mostly shared among a small number of countries: United States account for slightly more than 23%, followed by the European Union which hold a 20% of the total. Already at the top of this ranking, China accounts for around 12% of total historical emissions. Russia and India follow with a share slightly higher than 7 and 5% respectively (Figure 1, left panel). As our *historical responsibility* indicator is aimed at allocating a lower carbon budget to countries that emitted the most, the above-mentioned nations will receive the lowest shares. As for the current GDP per capita, which is a the base of the *economic capability* indicator, the wealthiest nations in 2015 are the Unites States, Australia, Canada, Japan and the European Union (Figure 1, central panel). They are, therefore, the countries required to support a higher portion of the global mitigation effort. Finally, Australia, Canada, United States, New Zealand and Russia are the top five nations in terms of emissions per capita, and that therefore will be required to reduce their emissions in order to converge toward an equitable per capita share in 2030 (Figure 1, right panel).

[7] see Chapter 4 for a full explanation of NDCs coverage and assessment.

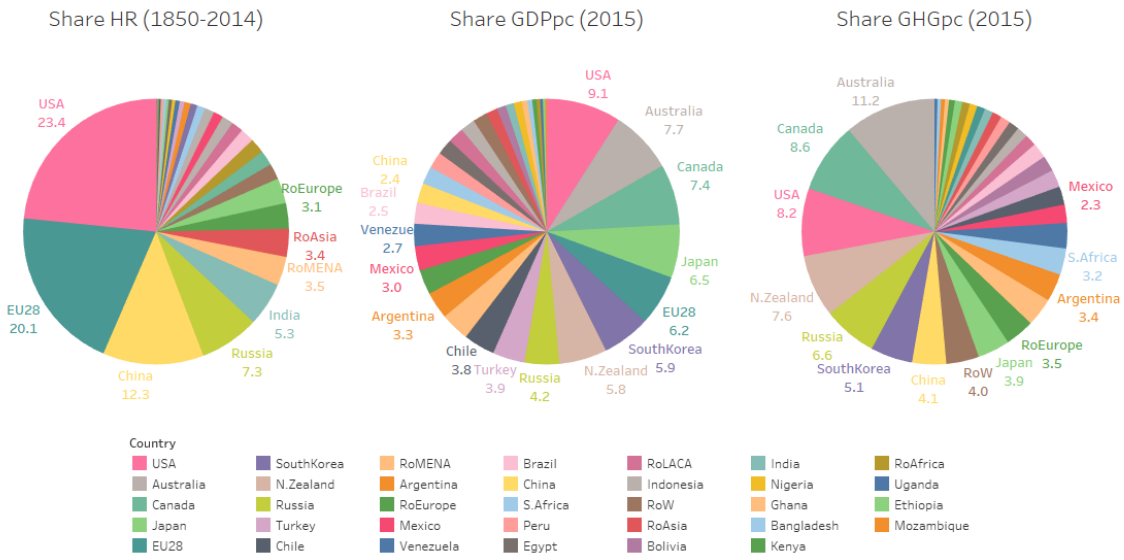


Figure 1: Share (%) of cumulative emissions 1850-2014, 2015 GDP per capita and 2015 GHG per capita

The main results of the equity-based indicators are summarized in the figures below. In particular, Figure 2 illustrates the emission debt (positive difference) or credit (negative difference) that countries have for the period 2015-2030 when their NDCs' emissions are compared with the budgets consistent with the 2°C limit and allocated according to each one of our ideal equity indicators. China, United States and Europe have the highest emissions debt for all the three categories. In all the three cases the gap generated when the criteria to distribute emissions allocation are *historical responsibility* and *economic capability* is approximately at the same level, whereas the emissions allocated taking into account the *equal individual rights* would allow them to emit a bit more by 2030. Other developed countries show a gap in all three approaches, even though the size is lower. These include the Middle East and North African region (RoMENA), where GDP and historical emissions have the major impact, followed by Russia, Japan, and Canada.

At the opposite side of the picture there are the less developed countries, whose NDC's are well below what they would be allowed to emit according our equitable distributions of carbon budget. In particular, Ghana, Uganda, Bolivia, Mozambique, Kenya, and Chile, have the largest emissions credit in terms of *historical responsibility*. If the *economic capability* is used as a benchmark, Mozambique, Ethiopia and Uganda have the widest remaining credit. Interestingly, India and is the only country among

major emitters to show a credit in one of the allocation criteria. Specifically, Indian emission intensity reduction objective is more ambitious than the allocation according to equal per capita emissions.

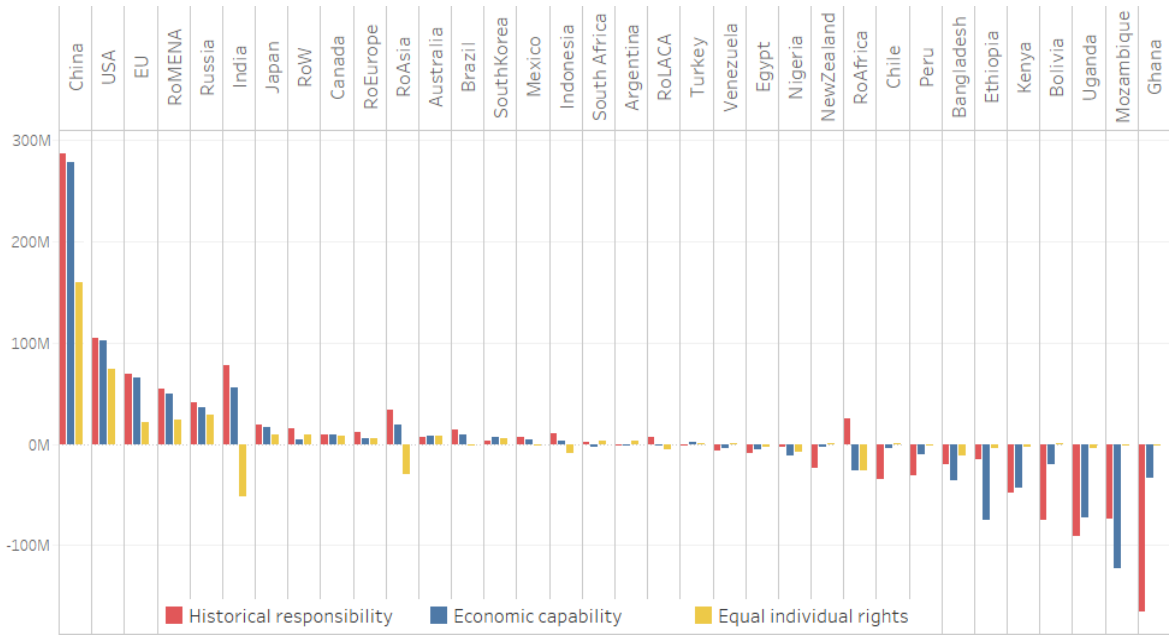


Figure 2: Difference between 2015 – 2030 NDCs emissions and equity-based allocation approaches (cumulative GHG, excl. LULUCF).

When the individual carbon budgets derived from the three approaches are aggregated in one single allocation, the results are strongly influenced by the chosen methodology (Figure 3). Overall, countries that receive a broader share of emissions under the *equal individual rights* approach are more favoured by the population-weighted voting method, which in some circumstances manages to lead to opposite results compared to the averaged aggregation. This is the case of India, RoAsia, Indonesia and the Rest of Latin American countries, which show an emission debt in the case of the averaged carbon budget (CB_A) and a carbon credit when the demographic weights (CB_D) are applied.

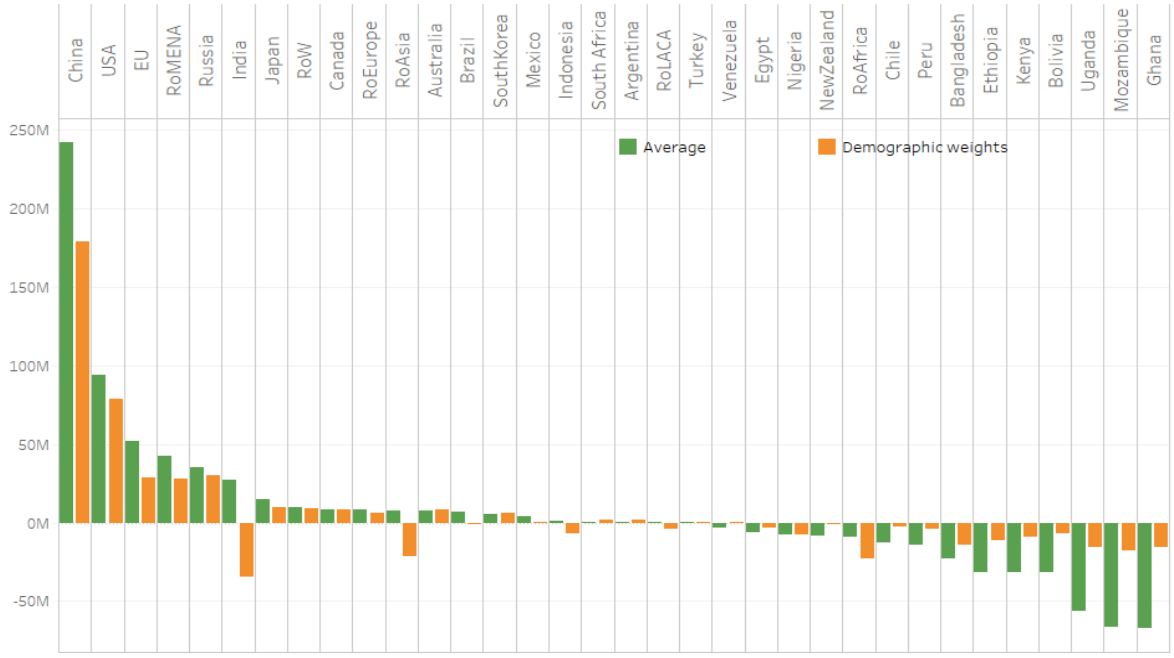


Figure 3: Difference between 2015 – 2030 NDCs emissions and aggregated equity-based carbon budgets (cumulative GHG, excl. LULUCF)

The reduction objectives of Turkey and Brazil are in line with our ideal equity-based benchmarks aggregated respectively using the average and the population voting approach. Overall, China, United States, the EU, the MENA region and Russia, are expected to run out their equitable allocation well before 2030, under both aggregation approaches. The sum of their NDC emissions represents alone 80% of the total available budget to keep the global temperature increase below 2°C. On the contrary, the carbon credit of less developed countries results wider under the averaged aggregation mainly because of the greater relevance this method gives to both *economic capability and historical responsibility* approaches.

As showed by the Figure 4, which reports the difference in percentage terms between the cumulative emissions projected under the NDCs and our combined equitable carbon budgets, the US should further increase the ambition of their NDC by 90% (CB_a) – 75% (CB_D) whereas Russia and China by about 85% if they would like to match the averaged equity allocation (CB_A) or 72 and 62% in the case of the weighted allocation (CB_D). In other words, the emissions that US, Russia and China plan to release in their NDCs are respectively in the range of about 9-4, 6.5-3.5, and 6-2.5 times higher than their equitable allocations.

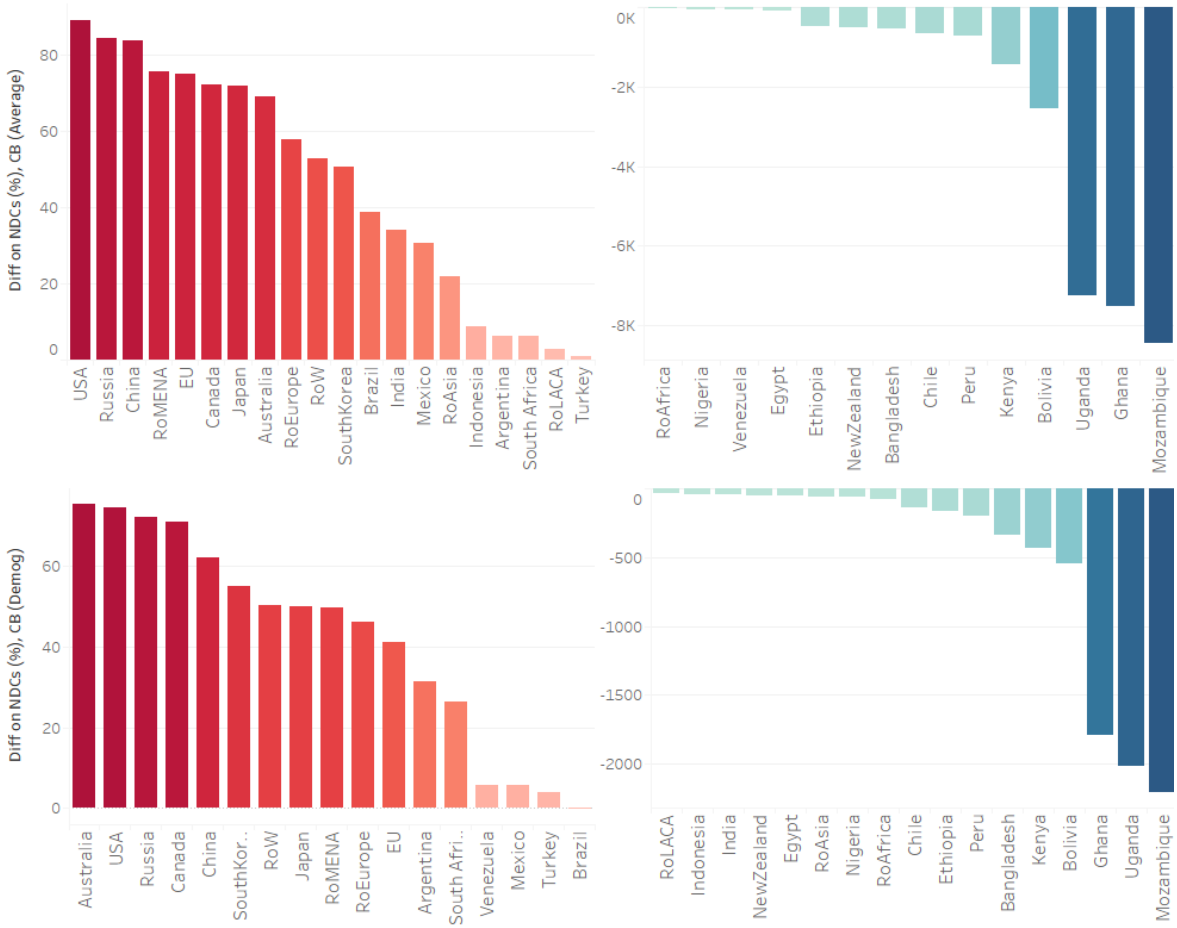


Figure 4: Difference (%) between NDC cumulative emissions and averaged CB (top panel) or demographic weighted CB (bottom panel)

Interestingly, the countries that experience a relevant difference in adopting one aggregation approach than the other are India, whose NDC results 43% lower than it should be according to our population weighted carbon budget (CB_D)and 34% higher if the average aggregation (CB_A) is used; the RoAsia region, that similarly shows a 22% surplus respect to their CB_A and, on the contrary, a 58% credit under the CB_D; the Rest of Latin America that in the latter case gains an emission credit of 34% (compared to a 3% debit under the CB_A) and Brazil, whose CB_D distribution is perfectly in line with the NDC submitted.

Both Middle East and North Africa (RoMena) and the EU proposed a mitigation objective that is 75% higher than their CB_A, but that decreases at 50% and 40% respectively if the CB_D is considered.

Canada, Japan and South Korea would be anyway required to submit a mitigation contribution in the range of 70% - 50% more ambitious than the current one.

On the contrary, among the countries that show a credit between the NDC emissions and the equitable average budget, Mozambique, Ghana and Uganda experience the largest difference in relative terms whatever the aggregation method, even though the size of their advantage is reduced under the CB_D (Figure 4). The credit that these countries have is about 90 to 70 times the emissions they plan to release in their NDC. Smaller but anyway relevant is the carbon budget still available for Bolivia, Kenya, Bangladesh, Peru, Ethiopia and Chile, which can ideally increase their 2015-2030 emissions by a consistent amount.

Taking a different perspective and comparing the amount of emissions derived from the NDCs as a share of the equitable average budget give us a better idea of the measure of developing countries' largest emission credit. The NDCs of Mozambique, Ghana and Uganda represent, indeed, only less than 5% of the budget at their disposal under the CB_D (or even less than 1.5 under the CB_A). Also Bolivia, which does not propose any quantitative emission reduction target, is projected to emit only 16% (or 4% if CB_A is used) of its total budget in 2030 if our three equity principles are applied jointly using the demographic weights.

Discussion and conclusions

Through the NDCs, countries, among other things, propose how they are planning to contribute to the global emission reduction by 2030. NDCs reflect a national view on what the single country's contribution should be both in terms of capability and fairness. As a flexible tool, the NDCs allow a regular update to be prepared also in the light of the periodic UNFCCC review of the progress toward the Paris Agreement's objectives. With the aim to contribute to this process, this essay compares the mitigation objectives included in the NDCs with a carbon budget consistent with the 2°C pathway and allocated according to three different equity approaches. Overall, we find that only a small number of countries proposed a NDC in line with our alternative equitable allocation of the carbon budget until 2030. Our results confirm that the mitigation contributions submitted by most of developed countries are far from being consistent with the objectives of the Paris Agreement in terms of either stringency or equity. A significant gap affects the NDC of major emitters and in particular those of US, China and Russia, whose equitable budget is expected to expire well in advance of 2030. India is the exception, with an emission gap relatively smaller than the other key

players and the NDC above of only one of the selected equity principles. Also Middle Eastern regions and the EU countries are required to propose more stringent emission reductions. On the contrary, the least developed countries will accumulate a consistent credit, accounting for a very small portion of emissions in each of our criteria.

From a methodological point of view, by including an approach based on more than one criterion and able to adjust responsibilities, capabilities and national circumstances over time, our framework represents a transparent and relatively easy way to measure NDCs efforts. As highlighted by the existing literature, however, the results are strongly influenced by how these principles are implemented and the methods to do it are many. This is confirmed by fact that the two alternative methods we use to aggregate the equity-based criteria lead to different – or even opposite - results for some countries.

We are also aware that, compared to other studies (Winkler, et al., 2013), our approach assigns a heavier burden to emerging economies in terms of historical responsibility and in the same way, influences positively the emission contribution of some developed countries. This is because of our choice to include also the most recent years in accounting for historical emissions (1850 – 2014). In fact, when looking at data, 50% of China's share of historical GHGs and more than 30% of India's have been emitted in the years from 2000 to 2014. For the same period, cumulative emissions of US and EU range between 19-15%. Nevertheless, we found no convincing reasons to exclude recent years' emissions, as they will represent future historical responsibility. And if part of the literature affirms that carbon emissions at the beginning of the industrial revolution were released without knowledge of the consequences, current emissions should be considered even more important as both awareness of the problem and availability of technology have improved. In the same manner, the fact that we exclude land use change and forestry emissions implies an underestimated contribution of Brazil and Indonesia. On a more fundamental level, intrinsic in ethical considerations about climate change there is a choice concerning social equity and income parity across countries (Ott & Sachs, 2000). If it is true that, as prescribed by the Paris Agreement and confirmed by our analysis, developed countries should bear the heaviest burden, they also have limited mitigation opportunities, while developing countries, which should have fewer obligations in tackling climate change, present greater opportunities of emissions reductions. This approach can be,

therefore, useful to assess climate finance obligations, to be provided in the form of international support from developed to developing countries. Nevertheless, the impact of climate funds are difficult to disentangle from other forms of development assistance as, by increasing investments, they can contribute to the economic growth of host countries. Implicit in the considerations about climate equity there is also a political choice about the ultimate economic and social goal to be reached at the international level, namely if convergence and eradication of socio-economic disparities across countries would be the common objective in the climate policy arena. While the convergence approach offers a consistent way to take into account for equity concerns, some have claimed that aiming at a world with equal GHG emissions, exactly as aiming at a world with equal GDP per capita, leads to standardization and represents a threaten to diversity (Ott & Sachs, 2000). In addition, the vulnerability aspects and the strong disparity on how they will affect countries are often disregarded in these kinds of evaluation. How to take into account all these aspects in the assessment of the Paris Agreement's future progress, certainly offer interesting insights for further research and methodological improvements.

References

Allwood, J. M. et al., 2014. Glossary. In: O. Edenhofer, et al. a cura di *Climate Change 2014:Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Aslam, M., 2002. Equal Per Capita Entitlements: A Key to Global Participation on Climate Change?. In: K. e. a. Baumert, a cura di *Building on Kyoto Protocol: Options for Protecting the Climate.* Washington, USA.

Botzen, W., Gowdy, J. & van den Bergh, J., 2008. Cumulative CO2 emissions: shifting international responsibilities for climate debt. *Climate Policy,* 8(6), pp. 569-576.

Bretschger, L. & Zue, F., 2013. Climate policy and equity principles: fair burden sharing in a dynamic world. *Environment and Development Economics,* Volume 18, p. 517–536.

Carraro, C., 2000. *Efficiency and Equity of Climate Change Policy.* s.l.:Springer-Science+Business Media.

Cazorla, M. & Toman, M., 2000. *International Equity and Climate Change Policy, Climate Issue Brief,* s.l.: RFF, Discussion Paper 27.

Chakravarty, S. et al., 2009. Sharing global CO2 emission reductions among one billion high emitters. *PNAS,* 106(26), p. 11884–11888.

Clarke, L. et al., 2014. Assessing Transformation Pathways. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III.* Cambridge University Press a cura di Cambridge: s.n.

Climate Action Tracker, 2016. *Tracking INDCs.* [Online] Available at: http://climateactiontracker.org/indcs.html [Accessed 21 March 2016].

Edenhofer, O. et al., 2014. *Climate Change 2014: Mitigation of Climate Change.Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Fleurbaey, M. et al., 2014. Sustainable Development and Equity. In: O. Edenhofer, et al. eds. *Climate Change 2014: Mitigation of Climate Change.Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate*

Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Grubb, M., 1995. Seeking fair weather: ethics and the international debate on climate change. *International Affairs,* 71(3), pp. 463-496.

Grubb, . M., Sebenius, J., Magalhaes, A. & Subak, S., 1992. Sharing the burden. In: I. M. Mintzer, ed. *Confronting climate change: risks, implications and responses.* Cambridge, UK: Cambridge University Press, pp. 305-322.

Gütschow, J., Jeffery, L., Gieseke, R. & Gebel, R., 2017. *The PRIMAP-hist national historical emissions time series (1850-2014). V. 1.1.* [Online] Available at: http://doi.org/10.5880/PIK.2017.001 [Accessed 23 06 2017].

Höhne, N. & Blok, K., 2005. Calculating historical contributions to climate change - Discussing the 'Brazilian proposal'. *Climatic Change,* Volume 71, p. 41–173.

Höhne, N., den Elzen, M. & Escalante, D., 2014. Regional GHG reduction targets based on effort sharing: a comparison of studies. *Climate Policy,* 14(1), pp. 122-147.

Howard, R., A., T., Stringe, L. & R.A., M., 2016. Environmental Science & Policy Which "fairness", for whom, and why? An empirical analysis of plural notions of fairness in Fairtrade Carbon Projects, using Q methodology. *Environmental Science and Policy,* Volume 56, p. 100–109..

International Monetary Fund, 2017. *World Economic Outlook Databas.* [Online] Available at: http://www.imf.org/external/pubs/ft/weo/2017/01/weodata/index.aspx [Accessed 29 07 2017].

Jacoby, H., Babiker, M., Paltsev, S. & Reilly, J., 2010. Sharing the burden of GHG reductions. In: J. E. A. &. R. Stavins, a cura di *Post-Kyoto international climate policy.* Cambridge, MA: Cambridge, MA: Massachusetts Institute of Technology, p. 753–785.

Keohane, R., 2016. *Keohane on climate: what price equity and justice?.* [Online] Available at: http://www.climatechangenews.com/2016/09/06/keohane-on-climate-what-price-equity-and-justice/ [Accessed 06 06 2017].

Kriegler, E. et al., 2013. Can we still meet 2°C with a climate agreement in force by 2020? The LIMITS study on implications of Durban Action Platform scenarios. *Climate Change Economics,* 4(4).

Kverndokk, S. & Rose, A., 2008. Equity and Justice in Global Warming Policy. *International Review of Environmental and Resource Economics,* 2(2), pp. 135-176.

Matthews, H. et al., 2014. National contributions to observed global warming. *Environmental Research Letters,* Volume 9.

Mattoo, A. & Subramanian, A., 2012. Equity in Climate Change: An Analytical Review. *World Development,* 40(6), p. 1083–1097.

Meyer, A., 2000. *Contraction & Convergence: The Global Solution to Climate Change.* Schumacher Briefings n.5 a cura di s.l.:Green Books.

Miller, D., 2009. Global justice and climate change: how should responsibilities be distributed?. In: G. B. Peterson, a cura di *Tanner lectures on human values.* Utah: University of Utah Press, pp. 119-156.

Morrisette, P. & Plantinga, A., 1991. The Global Warming Issue: Viewpoints of Different Countries. *Resources,* Volume 103, pp. 2-6.

Müller, B., 2001. Varieties of Distributive Justice in Climate Change. *Climatic Change,* Issue 48, p. 273–288.

Neumayer, E., 2000. In defense of historical accountability for greenhouse gas emissions. *Ecological Economics,* Volume 33, pp. 185-192.

O'Neill, B. et al., 2017. The roads ahead: narratives for Shared Socioeconomic Pathways describing world futures in the 21st century. *Global Environmental Change,* Volume 42, p. 169 – 180.

Ott, H. & Sachs, W., 2000. *Ethical Aspects of Emissions Trading,* s.l.: Wuppertal Institute Paper, 110.

Pan, X. et al., 2017. Exploring fair and ambitious mitigation contributions under the Paris Agreement goals. *Environmental Science and Policy,* Volume 74, pp. 49-56.

Peters, G. P., Andrew, R. M., Solomon, S. & Friedlingstein, P., 2015. Measuring a fair and ambitious climate agreement using cumulative emissions. *Environmental Research Letters,* Volume 10.

Rapauch, M. et al., 2014. Sharing a quota on cumulative carbon emissions. *Nature Climate Change,* Volume 4.

Ringius, L., Torvanger, A. & Underdal, A., 1999. *Burden Differentiation: reduction among countries,* s.l.: CICERO Working Paper..

Robiou du Pont, Y. et al., 2017. Equitable mitigation to achieve the Paris Agreement goals. *Nature Climate Change,* 7(1), pp. 38-43.

Rogelj, J. et al., 2016. Paris Agreement Climate Proposals Need a Boost to Keep Warming Well below 2 °C. *Nature,* 534(7609), p. 631–39.

Rose, A., 1992. Equity considerations of tradable carbon emission entitlements. In: S. Barrett, ed. *Combating Global Warming: Study on a Global System of Tradeable Carbon Emission Entitlements.* Geneva: UNCTAD, pp. 55-83.

Singer, P., 2002. One atmosphere. In: P. Singer, ed. *One world: the ethics of globalization.* New haven and London: Yale University Press, pp. 14-50.

Singer, P., 2002. *One world: the ethics of globalization.* New haven and London: Yale University Press.

Tavoni, M. et al., 2013. The distribution of the major economies' efforts in the Durban Platform scenarios. *Climate Change Economics,* 04(04).

UNFCCC, 1997. *Implementation of the Berlin Mandate, additional proposal by Parties.* s.l., United Nations Framework Convention on Climate Change.

UNFCCC, 2015. *Adoption of the Paris Agreement,* Paris: UNFCCC Conference of the Parties.Twenty-first session Paris, 30 Nov. to 11 Dec. 2015.

Winkler, H. & Beaumont, J., 2010. Fair and effective multilateralism in the post-Copenhagen climate negotiations. *Climate Policy,* 10(6), pp. 638-654.

Winkler, H., Letete, T. & Marquard, A., 2013. Equitable access to sustainable development: operationalizing key criteria. *Climate Policy,* 13(4), p. 411–432.

World Bank, 2017. *World Bank Open Data.* [Online] Available at: https://data.worldbank.org/ [Accessed 01 September 2017].

Can the Paris deal boost SDGs achievement? An assessment of climate mitigation co-benefits or side-effects on poverty and inequality

Introduction

At the end of 2015, two summit meetings took place that will lead to a redefinition of the international policy environment in the near future. In September 2015, the United Nations adopted the Sustainable Development Goals (SDGs), updating the Millennium Development Goals by defining broader and more ambitious development objectives that apply to all countries. Through 17 SDGs, the new 2030 Agenda for Sustainable Development addresses economic, social, and environmental sustainability and designs a pathway towards inclusive green growth. Three months later, in December 2015, the 21st UNFCCC Conference of Parties (COP 21) adopted the "Paris Agreement", which aims to strengthen the global response to climate change through a new regime of country-driven emission reduction and adaptation plans. In particular, the Agreement contemplates three major objectives: i) maintaining the increase in the global average temperature to well below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5°C; ii) increasing the ability to adapt to the adverse impacts of climate change and fostering climate resilience; and iii) mobilizing consistent finance flows to achieve mitigation and adaptation objectives (UNFCCC 2015).

Both frameworks represent a breakthrough from previous international attempts aimed at addressing these global challenges. In the 2030 Agenda for Sustainable Development, environmental and climate change objectives are integrated with traditional economic and development objectives, such as eliminating poverty and improving health and education, rather than treating these issues separately. In the Paris Agreement, the new bottom-up structure fosters a wider participation of countries than had been achieved under previous agreements. This includes

developing countries, which are allowed to propose their national contribution to the effort to deal with climate change by taking into account their national development priorities. This shift recognizes the need to adopt a comprehensive approach to global challenges, one capable of considering developmental and environmental challenges as intertwined. Clearly, a strong potential for interactions exists between efforts to achieve sustainable development goals and efforts to address climate change.

Early research into this topic helped to conceptualize the possible links between climate change mitigation policy and sustainable development. Some have suggested ways to strengthen potential synergies (Beg et al., 2002), and others have discussed opportunities for integrated policy making (Swart et al. 2003). More recent work has focused on quantifying the synergies and trade-offs between mitigation policy and other objectives (von Stechow et al. 2015, 2016). Despite these notable efforts, current integrated modelling research remains confined to sectoral studies offering a limited view on possible co-effects and focusing on a narrow set of specific objectives, such as the effect of mitigation on economic growth (Jakob and Steckel 2014), access to energy (Steckel et al. 2013) or air pollution (Rao et al. 2016).

This paper broadens the current perspective by providing an ex-ante assessment of the co-benefits and side-effects emerging from these new policy settings. In particular, this paper analyses how the commitments made by countries under the Paris Agreement will influence those countries' achievement of two specific SDGs: the prevalence of poverty (SDG1) and inequality (SDG10). The eradication of extreme poverty and the reduction of inequality are among the highest priorities in the broader effort to ensure sustainability worldwide. Their achievement is a preliminary and necessary condition for addressing all the other SDGs, including the environmental ones. Given the linkages between environmental and sustainable development objectives, analysing the effects of environmental regulation on development is critical.

The topic has a great importance for policy, since concern about possible trade-offs between climate change interventions and economic development are still perceived by developing countries as major obstacles to taking action to limit their greenhouse gas emissions. Indeed, it has been widely recognized that poorer segments of society are generally more vulnerable to negative climate impacts, especially where such events interact with and amplify non-climatic stressors (Olsson et al., 2014). It has also been argued that the costs of emissions reduction policies may further negatively impact the

poorest households, absent measures to offset the distributional impacts of those policies (Grottera et al. 2017; Goulder 2013; Büchs et al. 2011; Callan et al. 2009).

Existing cross-country research on the impact of climate change mitigation on poverty or inequality in developing countries has been narrowly focused. Prior to the Paris Agreement, international climate policy initiatives mainly relied on developed countries and the main research efforts have consequently been focused on the effect of the Kyoto Protocol's commitments of Annex I (or developed) countries on non-Annex I (developing) nations. Among the most prominent studies, Hussein et al (2013) estimate that a carbon tax on fossil fuels in Annex I countries leads to poverty reduction in most of the non-Annex I countries. However, when a forest carbon sequestration incentive (paid by Annex I parties) is added in the developing regions, the effect is reversed, with most low-income countries showing an increase in returns to the land, leading to reduced agricultural output and increased food prices.

Against this background, this paper aims at further enriching the debate by exploring the magnitude of impact of the new global climate policy framework - including mitigation contributions by both developed and developing countries – on poverty and inequality.

From a methodological point of view, our approach combines an empirical analysis with a modelling exercise performed by using a recursive-dynamic Computable General Equilibrium (CGE) model developed and enriched with SDGs indicators. CGE models are well-suited to assess the performance of economic indicators. Moreover, past modelling literature has highlighted the fact that they are also a powerful tool for assessing the evolution of key environmental indicators (Böhringer and Löschel 2006). Modelling social indicators in a CGE framework, however, is a difficult task, especially when these imply dispersion measures such as poverty prevalence and inequality at the core of SDG1 and SDG10. We overcome the representative agent structure proper of CGE models by relying on empirical literature and directly estimating the relationships between indicators and endogenous variables of the model (Bourguignon et al. 2005; Ferreira et al. 2010; Montalvo and Ravallion 2010). We characterise the future trend of poverty prevalence and inequality in the SSP2 baseline scenario, which is then used as a term of comparison to assess the impact of climate policy under different recycling schemes.

This approach allows us to shed light on the possible ancillary costs and benefits of mitigation policies. We are able to assess whether there is a trade-off between climate policy and economic/social development, and therefore how the implementation of climate policy could help to achieve other SDGs. Our results show that the full implementation of the emission reduction contributions as stated in the NDCs will slow down the effort to reduce poverty by 2030. The effect is greater in countries that have proposed a relatively more stringent carbon mitigation target, though the magnitude of the effect is limited. Countries with stringent mitigation objectives are likely, however, to experience a reduction of inequality compared to the baseline scenario levels. This suggests possible synergies between climate policy and the income increase of the poorest strata of the population. If financial support to mitigation action in developing countries is provided through an international climate fund, the prevalence of poverty is slightly reduced at the aggregate level compared to the mitigation scenario, but remains above the baseline levels.

The remainder of the paper is organized as follows. Section 2 briefly discusses the indicators selected to depict poverty and inequality, and describes their past trends. Section 3 reviews existing literature to estimate the determinants of inequality and poverty. Section 4 describes the modelling framework. Section 5 presents future projections of inequality and poverty compared to a baseline scenario. Section 6 briefly describes the policy context, including the NDCs presented under the Paris Agreement. Building on previous assumptions, Section 7 projects the future trends of inequality and poverty by assuming that the mitigation efforts under the Paris Agreement are fully implemented. Finally, Section 8 analyses the impact on SDGs of an international fund to supporting efforts in meeting NDCs by developing countries. Main conclusions are summarized in the final section.

Inequality and poverty within the Agenda 2030: measures and past trends

Of the seventeen Sustainable Development Goals (SDGs) outlined by the UN in Agenda 2030, two directly address poverty and inequality. In particular, SDG1 calls for ending poverty in all its forms everywhere. SDG10 calls for reducing inequality within and between countries (United Nations, 2015).

Both SDG1 and SDG10 are further articulated into more detailed targets that can be monitored through a set of quantitative and qualitative indicators (United Nations 2016). SDG1 is divided into 5 specific targets, the first of which calls for the eradication of extreme poverty, defined as the number of people living below the international poverty line of $1.25 per day. The four remaining components of SDG1 address additional important aspects, such as social protection, access to resources and basic services, and vulnerability to economic, social and environmental shocks. We agree that an effective understanding of poverty comprehends its multidimensional nature, however, for the purpose of this study we will use the poverty headcount ratio of $1.25 per day (World Bank, 2016) because of the wide data coverage and because it is readily quantified.[8]

Regarding SDG10, which addresses income inequality within and between countries, we concentrate specifically on SDG10.1. This subsection of SDG10 is focused on inequality within a single country, being specifically concerned with achieving "income growth of the bottom 40 per cent of the population at a rate higher than the national average" (United Nations 2015)[9]. Selecting the most suitable indicator to track progress on SDG10.1 is a complex matter. The Inter-agency and Expert Group on Sustainable Development Goal Indicators (United Nations 2016) chose the "per capita income growth of the bottom 40 per cent of the population." This indicator recalls target 10.1 but disregards the comparison of growth at different points of income distribution, which is at the core of the inequality concept. Therefore, we prefer a synthetic indicator of income dispersion. The Gini Index, widely adopted for national statistics, could have been the most natural candidate, but we have opted instead for the Palma Ratio, defined as "the ratio of the top 10% of population's share of gross national income (GNI), divided by the poorest 40% of the population's share of GNI" (Cobham and Sumner 2013). This indicator is an easy to compute and target-related measure of inequality. Moreover, in contrast to the Gini Index, which is oversensitive to the income of those in the middle of the distribution, the Palma ratio focuses on two specific points of distribution, which show higher variability across time

[8] We are also aware of the fact that the International Poverty Line (IPL) was recently updated by the World Bank to $1.90 per day (Cruz et al. 2015), but the "$1.25 per day" poverty line allows us to exploit a longer and wider panel data and to obtain a measure directly comparable to SDG 1.1.

[9] Acknowledging the importance of other inequality dimensions such as social, economic and political exclusion, opportunities and representativeness, we preferred a quantitative and widely available indicator of income inequality.

and countries than middle income deciles. Furthermore, its formulation is directly linkable to SDG10.1, and is easy to derive and communicate.

The figures below report the past trends for the two selected indicators worldwide and by geographic area[10]. 1990-2014 data from the World Development Indicators (WDI) show that the poverty headcount ratio constantly lowered worldwide (Figure 5), from about 35% in 1992 to 15% in 2012 (World Bank 2016). This was mainly driven by steep decreases in the East and South Asian countries, whereas the reduction was milder in sub-Saharan Africa.

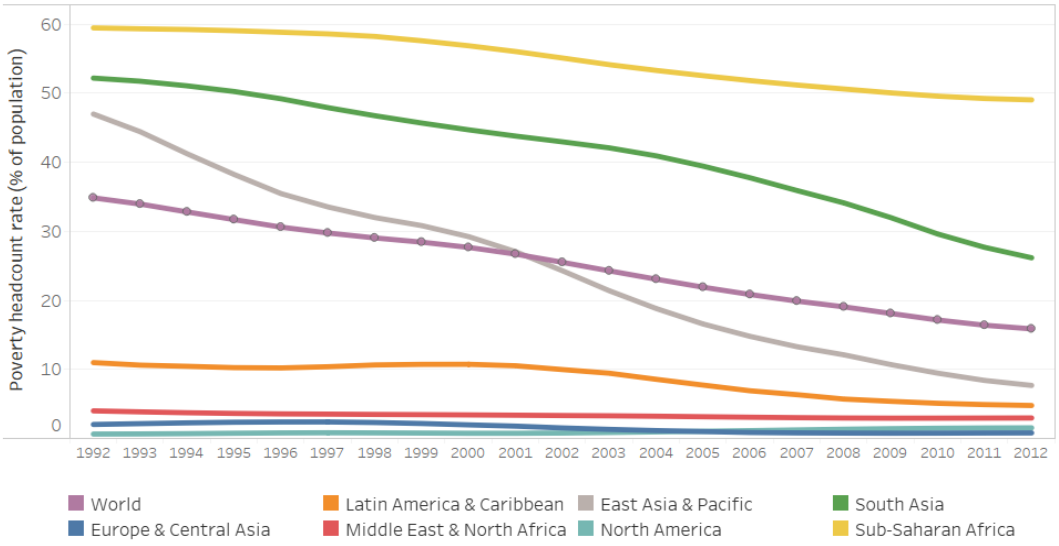


Figure 5 Poverty headcount ratio at 1.25$PPP per day for country aggregates and worldwide, 1992-2012 (5 year weighted average)

Inequality, measured as a population-weighted Palma ratio, increased slightly worldwide until 2001, and has since been decreasing (World Bank 2016). The drastic decline in inequality in Latin and South America since 2000 has driven the global pattern of inequality reduction, aided by more modest declines in sub-Saharan Africa. North America is the only region showing a clear increase in the disparities between rich and poor.

[10] World and regional-aggregate past trends of poverty and inequality are meant to give a general overview of the matter and overlook strong country-specific heterogeneity that will be better explored in Section 3.

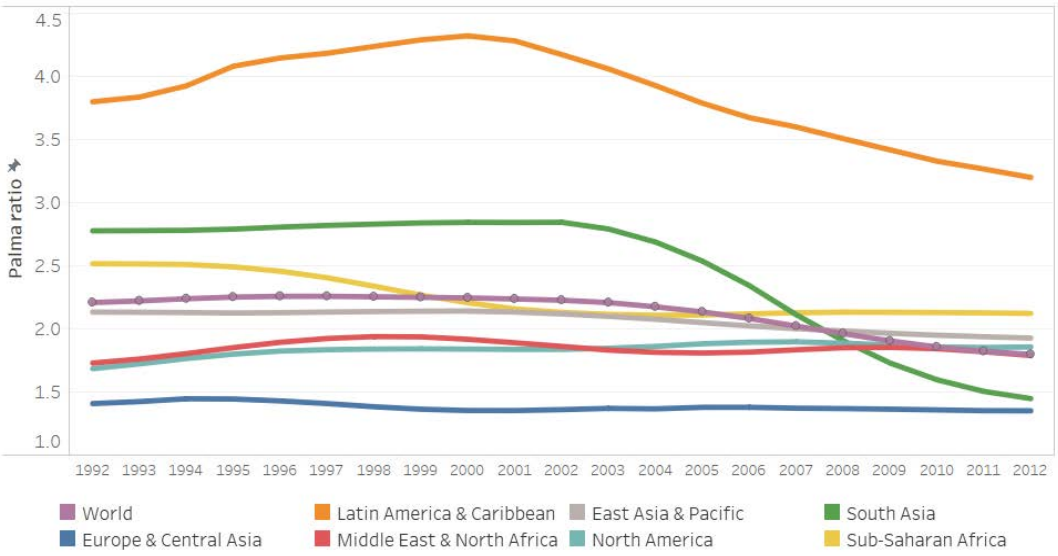


Figure 6 Palma ratio trend for country aggregates and the World, 1992 - 2012 (5 year weighted average)

Observing past trends of extreme poverty and inequality is a starting point, but it is fundamental to understand the determinants of these two indicators, in order to draw conclusions on their future patterns.

Inequality and poverty determinants in empirical and modelling literature

A broad empirical literature elucidates the determinants of poverty reduction from a cross-country perspective. Ravallion and Chen (1997) identify the growth of average per capita income as the main factor in reducing poverty. Ravallion (1997, 2001) and Heltberg (2002) highlight the importance of the structure of income distribution, which may undermine the inclusiveness of per capita income growth. Other country-specific empirical analyses also highlight the importance of sectoral growth patterns in explaining differentiated rates of poverty reduction across regions (Ferreira et al. 2007; Montalvo and Ravallion 2010).

Relevant literature on macro-economic modelling is more dispersed and, in general, focuses on single-country analyses. Nevertheless, two strands can be identified: the Microsimulation approach, which elaborates the outcome of the CGE model by using a microsimulation module that downscales the macro-economic result at the individual or group-level (Lofgren et al. 2013; Hilderink et al. 2009; Hertel et al. 2011; Bussolo and Lay 2003); and the Multi-Household approach that directly

integrates microdata in the macro-economic model and allows an endogenous poverty evolution (Boccanfuso et al. 2003).

Choosing the modelling approach depends greatly on data availability. The lack of country-specific data on the varied composition of income sources (and consumption expenditure) by income quantile makes it impracticable to use a Multi-Household approach and even a complex Microsimulation module, as in Bussolo and Lay (2003).

To compensate for a lack of available data, we build upon Lofgren et al. (2013), Hilderink et al. (2009), and other empirical literature on the topic, and run a panel regression in order to understand the link between the measure of poverty prevalence (Poverty headcount ratio at 2005$1.25 a day), average per capita income (GDP PPP2005 per capita), and the indicator of unequal income distribution (Palma ratio). Furthermore, we included a time trend (t) and country fixed effect.

$$\ln(POV_{i,t}) = \beta_1 \ln(GDPPPPpc_{i,t}) + \beta_2 \ln(Palma_{i,t}) + t + \varepsilon_{i,t} \quad (1)$$

In order to account for the heteroskedasticity and autocorrelation that characterise our panel, we use a linear regression model with robust standard errors, including a first order correlation within each panel. The data source is the World Development Indicator database (World Bank 2016). The panel considers 99 countries, both developed and developing, in the period 1990-2013.

Table 4 Linear regression model for panel corrected standard errors for Poverty headcount ratio at $1.25 a day.

	$\ln(\mathrm{POV}_{i,t})$
$\ln(GDPPPPpc_{i,t-1})$	-2.2588***
	(0.000)
$Palma_{i,t-1}$	0.2164***
	(0.000)
Constant	22.8937***
	(0.000)
Observations	511
Number of country	99
R^2	0.930

Robust pval in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The regression results are in line with existing literature and show a negative correlation between poverty prevalence and income per capita. That is, the number of people below the poverty line tends to shrink as GDP increases. However, increases in the Palma ratio is correlated with more people below the poverty line.

The determinants of income inequality are even more complex to disentangle than the causes of extreme poverty. Empirical studies suggest reductions in income inequality within and among countries have been achieved since the 1980s, especially within developing countries (Ravallion 2003; 2014). The determinants of this pattern can vary. In country-specific analyses, a major role can be played by the differential in labour productivity between agricultural and non-agricultural sectors (Bourguignon and Morrison 1998); reforms in the labour market; or an expansion of education and changes in population dynamics (Bourguignon et al. 2005). In cross-country analyses, the principle variables considered include sectoral wage differentials between skilled and un-skilled labour; globalization; education rates; market reforms; and policy interventions (Alvaredo and Gasparini 2015).

Regarding the macro-economic modelling literature (in particular CGE frameworks), income distribution is generally assumed to remain constant over time or exogenously imposed (van der Mensbrugghe 2015). An alternative option for tackling the possible evolution of inequality within a country is the Multi-Household approach, which allows for a heterogeneous response to macro-sectoral dynamics of household income and consumption choices. However, given the global perspective of our analysis and the lack of available data, modelling inequality with a Multi-Household approach is unfeasible. Instead, following the empirical strand of the literature, we run two unbalanced panel regressions for 120 countries (both developed and developing) in the period 1990-2013.

Our dependent variables are the share of GDP held by the richest 10% of the population, and that held by the poorest 40%. As explanatory variables, we consider some macroeconomic variables drawn from the World Development Indicator database and World Governance Indicators (World Bank 2016), which are consistent with the literature, characterised by a good country and year coverage, and directly linkable to endogenous variables in our CGE model.

We run two independent regressions with the following specification:

$$\ln(y_{i,t}^{p}) = \beta_0^{p} + \beta_1^{p}\ln(PEduExpsh_{i,t-1}) + \beta_2^{p}\ln(AgriVAsh_{i,t-1}) + \beta_3^{p}\ln(IndVAsh_{i,t-1}) + \beta_4^{p}\,CorruptCtrl_{i,t} + \beta_5^{p}\ln(Unempl_{i,t-1}) + \beta_6^{p}d\_c\_i_{i,t} + t^{p} + \varepsilon_{i,t}^{p} \qquad p = \{low40, high10\} \qquad (2)$$

where $y_{i,t}^{low40}$ and $y_{i,t}^{high10}$ are the shares of GDP held by the poorest 40% and the richest 10% of the population. The explanatory variables are: the share of Public Education Expenditure ($PEduExp\_sh$); the sectoral composition of the Value Added (VA) including the share of VA from agriculture ($AgriVA\_sh$) and industry ($IndVA\_sh$); an indicator on the perception of corruption control ($CorruptCtrl$); the unemployment rate ($Unempl$); and a dummy that distinguishes whether the dependent variable derives from a consumption or income distribution[11] (d_c_i). In addition, we include a time trend (t) and country fixed effects. Also in this case, we use a linear regression model with panel corrected standard errors that account for heteroskedasticity.

Table 5 Linear regression model for panel corrected standard errors for GDP share held by the poorest 40% and richest 10% of the population.

	$y_{i,t}^{low40}$	$y_{i,t}^{high10}$
$PEduExp\_sh_{i,t-1}$	0.0227**	-0.0188***
	(0.021)	(0.009)
$\ln(AgriVA\_sh_{i,t-1})$	0.1220***	-0.0861***
	(0.000)	(0.000)
$\ln(IndVA\_sh_{i,t-1})$	0.1989**	-0.1358**
	(0.013)	(0.014)
$Corrupt\_cntr_{i,t}$	0.0295	-0.0186
	(0.168)	(0.334)
$Unempl_{i,t-1}$	-0.0033*	0.0024
	(0.084)	(0.113)
$d\_c\_i_{i,t}$	0.0151	0.0020
	(0.436)	(0.913)
t	0.0090***	-0.0066***
	(0.000)	(0.000)
Constant	-16.1529***	17.3423***
	(0.000)	(0.000)
Observations	663	663
Number of country	120	120
R^2	0.225	0.188

pval in parentheses

*** p<0.01, ** p<0.05, *p<0.1

[11] The dummy variable (d_c_i) assumes value 1 when the dependent variable derives from a consumption distribution, value 0 in the case of income distribution. Following Alvaredo and Gasparini (2015), we include this dummy to account for the wedge between income and consumption-based inequality measures.

The income share of the poorest 40% of the population is correlated positively with the GDP share devoted to public education, the VA share generated in agriculture and industry, and a high level of corruption control[12]. Implicitly, there is a negative correlation between the income share of the poorest and the VA share from services (residual to agriculture and industry shares). This result is in contrast with country-specific literature on poverty, which generally identifies the growth of tertiary sector output as a factor benefiting the poor (Ferreira et al. 2010). However, it is worth specifying that our analysis has a cross-country perspective: the countries experiencing the highest levels of inequality are developed countries with a big tertiary sector. The explanatory variables for the income share of the richest 10% of the population show opposite signs and similar magnitude.

It is necessary to understand the main determinants of poverty and inequality in the past to envision the future trend of these two indicators, which will then be characterized by the same relationships with explanatory variables in Equations (1) and (2), but mutated macroeconomic conditions.

The modelling framework

Projecting the evolution of inequality and poverty prevalence and assessing the impact of environmental policies on these social indicators require some assumptions on the future socio-economic scenario and a modelling framework to recreate it.

The Inter-temporal Computable Equilibrium System (ICES) model (Eboli et al. 2010) is at the core of our modelling framework (see Appendix I for more details). ICES is a recursive dynamic CGE model: a multi-market model linked to current real economy data observed in the benchmark year, based upon the merging of national social accounting matrices into a global economic database GTAP8 (Narayanan et al. 2012). ICES makes it possible to draw scenario-dependent evolutions of Global socio-economic conditions; in addition, satellite databases on CO2 and non-CO2 emissions and energy volumes connected to production and consumption flows offer insights into the consequences of economic growth on the environment in an internally consistent framework.

[12] The indicator on control of corruption (WB 2016) ranges from approximately -2.5 (weak control) to 2.5 (strong control).

The two targets illustrated in SDG1.1 and SDG10.1 and the related indicators described in Section 3 go beyond the socio-economic representation of the world that is proper to CGE models because they are both related to the concept of income distribution across agents within a country, which is not captured in a context of country-representative households of CGE models. In Section 3, we described some papers that introduce household heterogeneity into a general equilibrium framework, but the number of countries and macro-aggregates characterising our analysis prevent us from proceeding in that direction.

Therefore, we directly exploit the relations identified in Equation 2 that connect inequality levels to the sectoral structure of the economy, public investment in education, the unemployment rate and corruption control during the period 1990-2013. Assuming the stability of this relation across time, we run two out-of–sample predictions for the shares of GDP held by the poorest 40% ($y_{i,t}^{low40}$) and the richest 10% of the population ($y_{i,t}^{high10}$), and compute the Palma ratio for the period 2007-2030, where the historical values of dependent variables are replaced by outputs of the ICES model under the selected scenarios. A similar procedure is used for determining the future poverty rate: the coefficients estimated in Equation 1, pertaining to the period 1990-2013, are used in an out-of-sample prediction for the period 2007-2030, where the explanatory variables are an endogenous output of the model (GDP per capita) or its derivation (the Palma ratio computed from the out-of–sample predictions of Equation 2).

Linking poverty and inequality measures to ICES makes it possible to assess in a consistent framework the influence of socio-economic variables and/or policy interventions in achieving SDG1.1 and SDG10.1. Clearly, the analysis depends heavily on the assumptions on the future socio-economic conditions that characterised the baseline scenario.

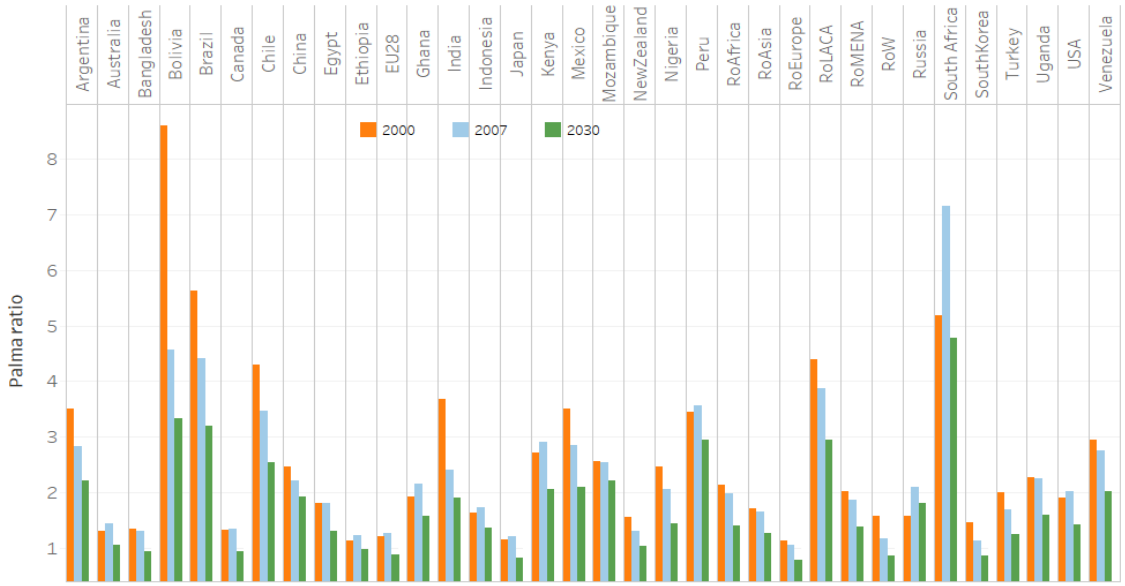
Inequality and poverty trends up to 2030: the baseline scenario

As a reference source for our scenario, we use the Shared Socioeconomic Pathways (SSPs) developed by the climate model community (O'Neil et al. 2017). SSPs envision possible future scenarios characterised by differentiated patterns of population, employment and economic growth, energy intensity, emissions, and land cover. These future paths are therefore related to different mitigation/adaptation

challenges. Exogenous drivers in the ICES model, such as primary factor productivity, sector-specific efficiency, total factor productivity, population, employed, and energy prices are then used in order to calibrate the endogenous variables – namely GDP, energy use, emissions and value added shares – that characterize a specific SSP.

The baseline reproduces the Shared Socio-Economic Pathway 2 (SSP2) with 3.6 W/m2 radiative forcing in 2030 (on the path of 7.5 W/m2 and 4°C in 2100), and it will then be used as a benchmark to assess the effects of mitigation scenarios arising from the outcome of COP21. SSP2 is defined as the "middle of the road" scenario, characterised by similar dynamics observed in recent decades, but that imagines some progress in achieving development goals. Income per capita grows globally at a medium pace and also population follows the UN medium projection scenario. Income convergence between countries is slow, but intra-country inequality diminishes. Resource and energy intensity slows down, as well as dependence on fossil fuels.

Combining ICES results from the SSP2 scenario with the coefficients estimated in Equation 2, we are able to estimate how intra-country inequality will evolve up to 2030. Results are reported in Figure 7, which shows the estimates of the Palma ratio in 2030, compared with the historical figures in 2007 and 2000.[13]



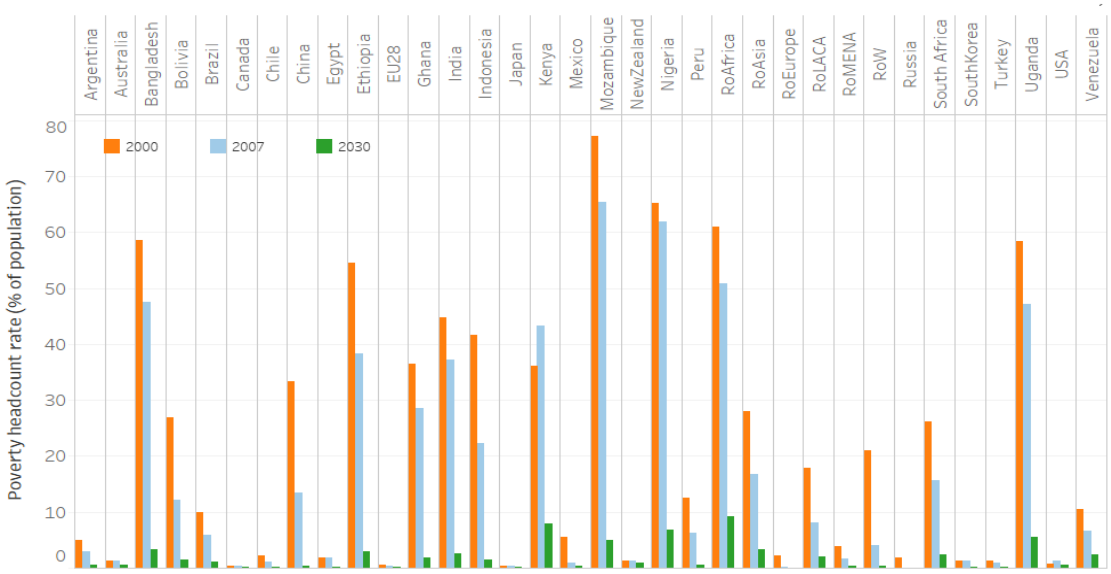
Source: Palma ratio in 2000 and 2007 is computed from WDI; model results are used for 2030.

Figure 7 Palma ratio in 2000, 2007 and in 2030 SSP2 baseline scenario

[13] The out-of-sample predictions use all explanatory variables of (2; moreover, it is worth pointing out that the unemployment rate is an exogenous variable in ICES, and the perception of corruption control is maintained constant after 2013.

Between 2000 and 2007, the worldwide average Palma ratio decreased by 9%, with significant differences amongst countries. Changes in the Palma ratio in this period range from a decrease of 47% in Bolivia to an increase of 38% in South Africa. In the SSP2 scenario, the Palma ratio is projected to continue dropping, with the worldwide average 23% lower in 2030 compared to 2007, driven by an increase of income share held by the poorest 40% of the population (+17%) and a decrease of the income share of the richest 10% of the population (-10%). By 2030, inequality decreases in all countries compared to 2007, but the rate of reduction will slow down in Latin America compared to the rate of decrease from the 2000-2007 period. Instead, the gap between the income of rich and poor in several developed countries and some developing countries decreases because of lower unemployment rates and slightly increasing agricultural VA shares in the former case, and a rise in both the VA share from industry and the public education expenditure share in the latter case.

Combining these projections for the Palma ratio with the per capita evolution of GDP, we are able to compute the future path of the poverty rate (Equation (1). Figure 8 illustrates the strong reduction of poverty prevalence in Asia and Sub-Saharan Africa estimated by the model, driven by rising per capita income and the decreasing intra-country inequality. The past worldwide trend showed a 28% reduction of poverty prevalence between 2000 and 2007. By 2030, the estimated number of people below the $1.25 poverty line will have decreased by 86% compared to the 2007 levels (in absolute terms, this represents 1 billion fewer people living below this poverty line as compared to 2007). Overall extreme poverty persists into 2030, however, affecting around 2% of the global population (162 million people). Despite this impressive reduction, some countries in Africa and Asia still show significant poverty rates in 2030. In particular, this is the case of Kenya, Nigeria and the Rest of the Africa region (RoAfrica), where respectively 8%, 7% and 9% of the population will live below the $1.25 poverty line in 2030 (around 65 million people). Our results stem from a socio-economic scenario characterized by sustained growth rates and decreasing inequality in developing world, but they present some similarities with the optimistic trajectory described in Ravallion (2013). It is worth mentioning that alternative scenarios considering lower GDP growth or higher population growth could determine a slower reduction of poverty prevalence.



Source: Poverty headcount in 2000 and 2007 is computed from WDI; model results are used for 2030.

Figure 8 Poverty headcount rate in 2000, 2007 and 2030 SSP2 baseline scenario

Policy scenario: the Paris Agreement and the NDCs

The central element of the Paris Agreement are the "Nationally Determined Contributions" (NDCs), which are plans each country autonomously determines to deal with climate change from 2020 on. All parties to the Paris Agreement, including both developed and developing countries, are called to adopt and communicate an NDC. Although the NDCs represent a breakthrough in the scope of participation in the international effort to address climate change, they are widely heterogeneous, in both stringency and coverage of mitigation efforts. While developed countries generally frame their contributions in the form of a quantified economy-wide mitigation effort in comparison to a reference year, developing countries usually refer to emission intensity, or link their emission reduction target to a Business As Usual (BAU) scenario. In addition, most developing countries define both an unconditional and a conditional target: the former to be achieved with internal funds and capabilities, and the latter including a more ambitious mitigation effort to be undertaken on the condition that external financial and technical support be provided.

To perform this modelling exercise, we focus on the conditional mitigation objectives stated in the NDCs.[14] Due to modelling limitations, the GHG emission targets that are part of the NDCs are applied only to CO2 emissions. The emission levels in

[14] As reported in the UNFCCC's NDC interim registry. For Parties whose NDCs are not yet available we referred to the /NDCs available on the UNFCCC's INDC platform.

2030 are computed by using data from CAIT (WRI 2016) for countries committing to an emission reduction with respect to a specific year, whereas the SSP2 baseline scenario is used as a reference when the reduction is relative to the BAU scenario. In addition, we also want to assess the effect of these emission reduction measures in the presence of a fund that supports developing countries in realizing their climate change actions. The Paris Agreement reaffirms the commitment of the developed nations to make available increased financial flows to developing countries, starting from the 2020 pledge to mobilize USD 100 billion per year. We simulate this flow of climate finance with the objective of understanding the role that funds like the Green Climate Fund can play in supporting the developing economies in reaching their emission reduction targets.

The proposed mitigation scenario considers an effort to curb emissions starting in 2013 and assumes that each country achieves its NDC by 2030. The European Union (EU28) implements an Emission Trading System (ETS), as already foreseen by the EU ETS domestic legislation, while all other countries achieve their contributions unilaterally with a domestic carbon tax. China, India and Chile have expressed their NDCs in terms of emission intensity; this peculiarity is preserved in the modelling policy scenario. The mitigation objectives considered for each country are detailed in Table 5. In some cases, countries are clustered in regional groups to which a common target is attributed.[15]

The mitigation scenario is characterised by two different recycling schemes of the revenues collected from the carbon market or the carbon taxes:

- MPOLICY scenario: revenues are redistributed internally;
- MPOLICY+GCF scenario: part of the revenues from the developed countries flows into an international fund aimed at supporting mitigation action in the developing countries. We use the allocation rules of the Green Climate Fund (GCF) as a benchmark (see Section 8). Money is transferred to the developing countries[16] in Asia,

[15] In defining the emission reduction target per aggregates of countries, we computed each country's target emission level in 2030 by converting the otherwise specified NDCs (targets on emission reduction with respect to a specific year, emission levels, emission intensity, and deviation from BAU scenario). The macro-region target emission level is compared to emission levels in the BAU scenario, and the aggregate emission reduction is so derived.

[16] Among GCF recipient countries, we included those countries that have up to now selected the National Designated Authorities (excluding China) according to GCF rule: http://www.greenclimate.fund/partners/countries/nda-directory.

Latin America, the Middle East and Africa, and is used to subsidize specific mitigation-related sectors: namely, Clean Electricity and Research&Development (R&D)[17].

Table 6 Emission reduction target in 2030

Country	Target (%)	Target type	Country	Target (%)	Target type
Australia	-27	Emission reduction wrt 2005	**Venezuela**	-20	Emission reduction wrt 2030 BAU scenario
New Zealand	-30	Emission reduction wrt 2005	**Rest of Latin America (RoLACA)**	-20	Average mission reduction wrt 2030 BAU scenario
Japan	-26	Emission reduction wrt 2013	**EU28**	-40	Emission reduction wrt 1990
South Korea	-37	Emission reduction wrt 2030 BAU scenario	**Rest of Europe (RoEurope)**	-17	Average mission reduction wrt 2030 BAU scenario
Bangladesh	-15	Emission reduction wrt 2030 BAU scenario	**Russia**	-27.5	Emission reduction wrt 1990
China	-62.5	Emission intensity reduction wrt 2005	**Turkey**	-21	Emission reduction wrt 2030 BAU scenario
India	-34	Emission intensity reduction wrt 2005	**Rest of MENA (RoMENA)**	-9	Average mission reduction wrt 2030 BAU scenario
Indonesia	-41	Emission reduction wrt 2030 BAU scenario	**Ethiopia**	-64	Emission reduction wrt 2030 BAU scenario
Rest of Asia (RoAsia)	-25	Average mission reduction wrt 2030 BAU scenario	**Ghana**	-45	Emission reduction wrt 2030 BAU scenario
Canada	-30	Emission reduction wrt 2005	**Kenya**	-30	Emission reduction wrt 2030 BAU scenario
USA	-27	Emission reduction wrt 2005	**Mozambique**	-8	Emission reduction computed from target emission levels in 2030
Mexico	-36	Emission reduction wrt 2030 BAU scenario	**Nigeria**	-45	Emission reduction wrt 2030 BAU scenario
Argentina	-30	Emission reduction wrt 2030 BAU scenario	**Uganda**	-22	Emission reduction wrt 2030 BAU scenario
Brazil	-37	Emission reduction wrt 2005	**South Africa**	-22	Emission level target in 2030 is in the range 398 and 614 Mt CO2–eq
Chile	-40	Emission intensity reduction wrt 2007	**Rest of Africa (RoAfrica)**	-33	Average mission reduction wrt 2030 BAU scenario
Peru	-30	Emission reduction wrt 2030 BAU scenario	**Rest of the World (RoW)**	-36	Average mission reduction wrt 2030 BAU scenario

[17] The allocation of subsidies across the two sectors depends on the magnitude of the sectors itself: e.g. the highest is R&D VA compared to the Clean Electricity one, the more it is subsidized.

Poverty and inequality in the mitigation scenario

The worldwide implementation of the conditional NDCs yields a 19% reduction of CO_2 emissions at the global level in 2030 with respect to the SSP2 baseline scenario (13% reduction of GHG emissions). Achieving the mitigation targets (the MPOLICY scenario) imply an economic cost of between -6.7% and +5.6%, computed with respect to the countries' GDP in the baseline scenario in 2030 (Figure 9).

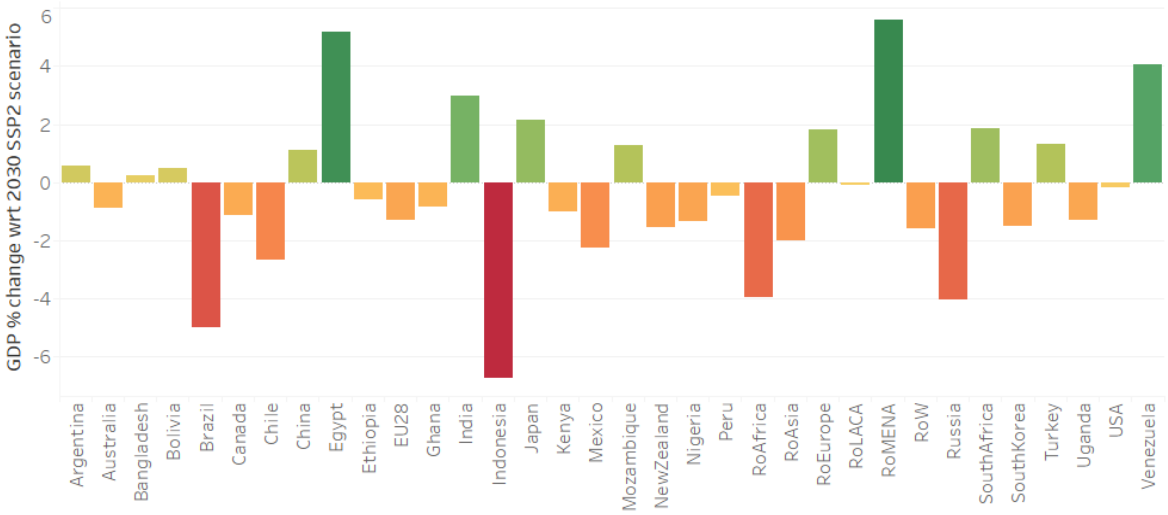


Figure 9 Mitigation policy cost in terms of GDP in 2030, MPOLICY scenario with respect to SSP2 baseline scenario

The situation at the country level is highly heterogeneous. Some countries experience GDP gains as a consequence of absent or loose NDC mitigation targets (Figure 10). This happens in Japan, China, India, Venezuela, non-EU European countries, Turkey, Egypt, and part of the Middle-East and South Africa, that have relatively lower carbon taxes and, therefore, higher competitive advantages in comparison with other countries.

In particular, China, India and Bolivia are projected to reach higher emission levels under the mitigation policy scenario than in the baseline, experiencing a clear leakage effect as a consequence of the weak mitigation target stated in their NDCs. On the contrary, countries such as Indonesia, Brazil, Chile, Russia and RoAfrica, whose targets appear to be relatively more stringent, are projected to experience a substantial GDP loss to achieve their mitigation objectives.

Although not fully comparable at the geographical scale, our results are consistent with other recent estimates that assess the cost of mitigation action under the Paris Agreement by using similar scenario assumptions (see Aldy et al., 2016).

Some caveats must be noted. In the case of Indonesia and Brazil, which show the highest GDP losses, we need to acknowledge that our model does not fully capture the economic potential of these countries in terms of emission reduction from the forestry sector. Although both their mitigation objectives are economy-wide, reforestation and reduced deforestation are certainly an economically viable mitigation opportunity for these countries (Smith et al. 2104). Similarly, China's action, as stated in both the NDC and the subsequent 13th Five Year Plan (2016–2020), is broader than the quantitative carbon intensity target used for our analysis. In particular, the planned increase in the non-fossil fuel share and the recently-imposed limit on coal consumption, if maintained up to 2030, might lead to steeper emission reductions (and potentially higher costs) than those projected in our mitigation scenario. In addition, mitigation actions are achieved unilaterally by each country (excluding the EU-28 members). The literature usually agrees on the fact that the costs of climate action are lower if cooperative mechanisms are implemented (Clarke et al., 2009). However, despite the fact that the Paris Agreement explicitly opens up to the possibility for countries to use "Internationally Transferred Mitigation Outcomes" (ITMOs), at the moment there are not enough elements to figure out how such a mechanism will be designed. Finally, none of the results of our scenarios considers the avoided damages (and costs) from emission mitigation action, which will be addressed in future research efforts.

Figure 10 Stringency of mitigation policy in 2030, CO2 emissions in MPOLICY scenario with respect to SSP2 baseline scenario

To better describe the effects of mitigation policies on SDG1 and SDG10, i.e. poverty prevalence and inequality, we focus only on a narrower set of countries that show high to moderate poverty headcount rates in the base year (2007).

Figure 11 portrays how poverty headcount ratio and inequality (Palma ratio) in 2030 are affected by climate policy.

In general, countries with a stringent mitigation policy experience a reduction of inequality compared to the baseline scenario levels. This is the case in Ethiopia (-8%), Nigeria (-4%), Indonesia (-3%), and Brazil (-3%). The forces behind these changes are a country-specific adjustment of sectoral VA and of public education expenditure[18]: the increase in agriculture and manufacturing shares, as well as that of public education expenditure, play a major role in Indonesia and Brazil. As explained in Section 3, the empirical analysis on cross-country historical data highlighted that these drivers have a positive impact on income share of the poorest 40% of population (and a negative

[18] In all policy scenarios, government expenditure in real terms is assumed to be unchanged compared to the baseline scenario one; therefore, whether or not policy implementation determines a contraction in GDP, the share of GDP devoted to public expenditure in education increases because the government is forced to maintain its expenditure unchanged.

impact on the income share of the richest 10%). In Ethiopia, the mitigation policy determines a small contraction of agricultural production (negatively effecting the Palma ratio), but fosters manufacturing and heavy industry (which has a positive effect on the Palma ratio). In fact, despite the contraction of fossil fuel intensive sectors, VA in heavy industry rises because of a switch to clean electricity. The increase in public expenditure in education is the main driver for Nigeria.

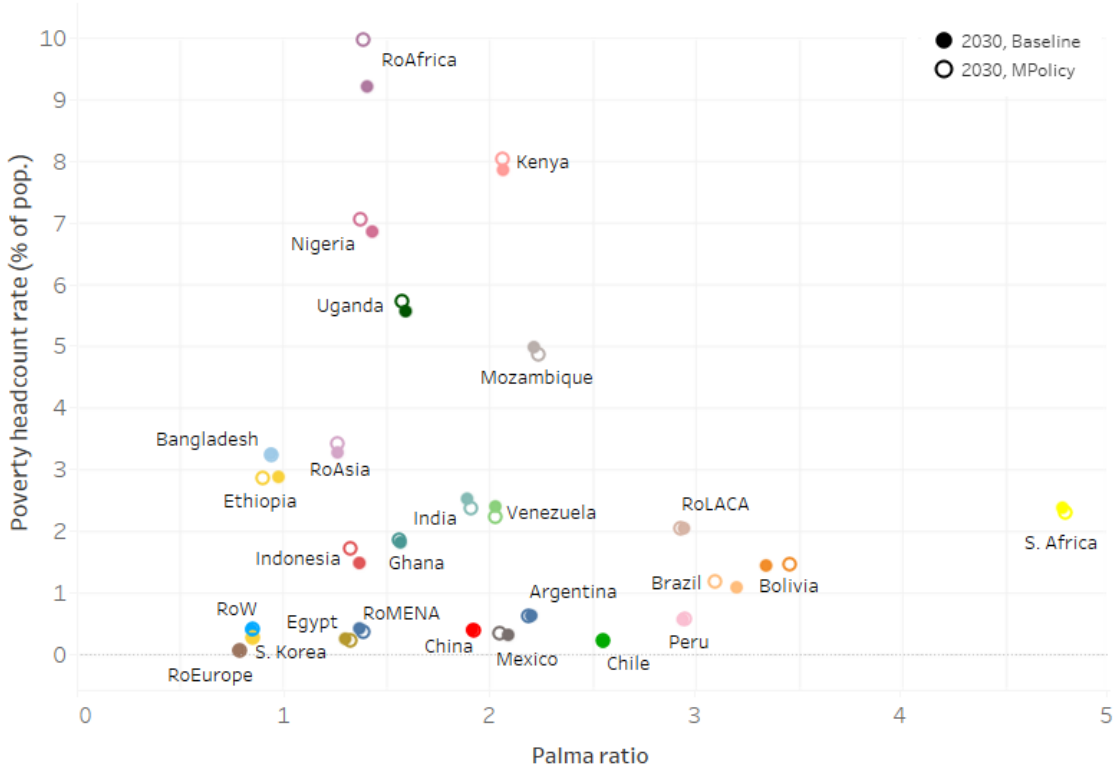


Figure 11 Palma ratio and poverty prevalence in 2030, MPOLICY and SSP2 baseline scenario

The countries gaining from the climate policy because of a non-stringent NDC show higher inequality than in the baseline scenario. Bolivia is a clear example of this pattern, with an increase of approximately 4% in the Palma ratio. The contraction of the industrial sector, highly dependent on more costly imported energy, is behind this result.

The outcome in terms of poverty prevalence reduction with respect to the 2030 baseline scenario, is mixed and depends on how the composition of both income and inequality is affected by the policy. Worldwide poverty prevalence increases by 2% (nearly 3 million people) compared to the baseline scenario (Figure 11). The mitigation policy accelerates poverty reduction in RoMENA (-10%), Egypt (-9%), Venezuela (-7%),

India (-6%), South Africa (-3%) and Mozambique (-2%). In these countries, the slight rise in inequality is more than compensated by economic gain coming from a non-stringent climate policy. Ethiopia is the only country in which the reduction of inequality (-8%) due to the policy more than compensates the cost of mitigation (-0.6%) and determines a slight reduction of poverty prevalence compared to the baseline scenario (-0.5%).

Three countries show a substantial rise in poverty prevalence: Indonesia (15%), Brazil (9%) and RoAfrica (8%), where the economic costs of mitigation policy are not compensated by the inequality reduction.

It is worth remembering that this assessment considers only the possible abatement cost for the society without accounting for the climate policy benefits, such as the consequent reduction of climate change-related damage. According to the recent literature, climate change impacts will have strong distributional and poverty implications (Dennig et al. 2015); therefore not accounting for them implies an overestimation of mitigation costs.

Furthermore, our results rely on assumptions about economic growth and the carbon intensity of the selected baseline scenario. However, the comparative outcome of the mitigation policy with respect to the baseline scenario in terms of poverty and inequality should not be altered by a lower GDP growth or carbon intensity. Moreover, a sensitivity analysis on scenario assumptions could be an interesting topic for future research.

Poverty and inequality under the mitigation scenario with the Green Climate Fund

In order to recreate a more realistic scenario of the COP21's aftermath, we design a further recycling rule of carbon revenues, according to which the developed countries, committed to an emission reduction objective in their NDCs, devote a part of their revenues to an international fund aimed at supporting the developing countries' climate action (MPOLICY+GCF scenario). Following the actual allocation rules adopted by the Green Climate Fund's Board so far, we design the fund in order to achieve an "equal balance between adaptation and mitigation" actions, as well as a "geographic balance and a reasonable and fair allocation across a broad range of countries" (GCF, 2014). Since, for the moment, we consider only the support to mitigation actions, our

fund will reach $50 billion (US$2007) in 2020 (50% of the pledged $100 billion a year by 2020) and then remains constant. The funds are then distributed across beneficiary countries proportionally to their population share (Figure 12). Assuming an equal percentage contribution among the donors, to reach the planned amount, they donate 7% of their carbon revenues up to 2020 and then slightly reduce them progressively. The major contributors to this fund are the EU28, providing 41% of the total amount, and the United States, with 28%.

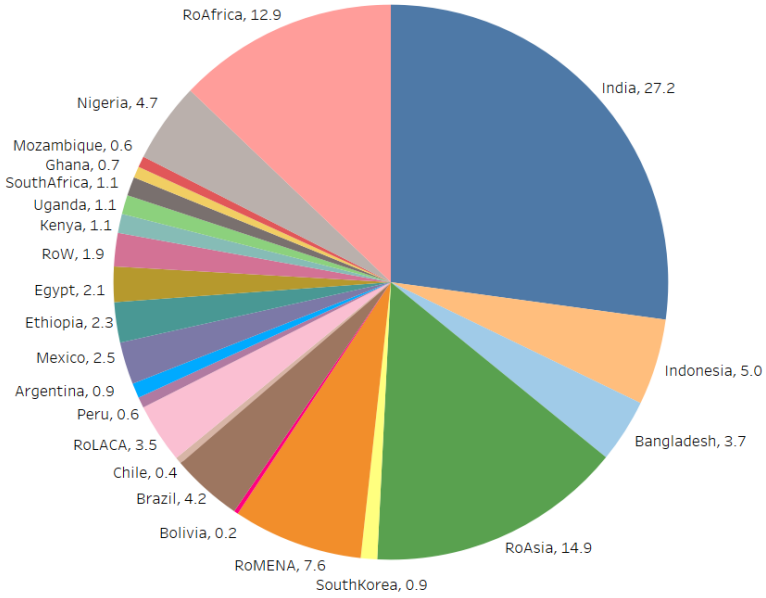


Figure 12 Developing fund recipients

In the MPOLICY+GCF scenario, the developing countries receive the funds and use them to subsidise clean electricity and R&D sectors. This recycling scheme determines a small drop of inequality (0.2% globally) by 2030 compared to the MPOLICY scenario. The results are quite heterogeneous at the country level (Figure 13) and appear unrelated to the share of funds received, but rather to the magnitude of the funds with respect to the country's economy. Ethiopia, which obtains only 2.5% of the GCF's funds (corresponding to 1.3% of its GDP in 2030), experiences the highest inequality reduction (9.3% with respect to the 2030 MPOLICY scenario), which follows a 35% increase of VA share generated in the industrial sector and a 1% rise in the expenditure share for public education. In Bolivia, the small fraction of international money that flows into the country (i.e. 0.3% of its GDP) determines a 0.7% reduction in inequality, due to the rise in production in the Clean Electricity and R&D sectors. In Nigeria and Mozambique, the Palma ratio shows the highest upsurge, increasing respectively by

0.5 and 0.6% compared to the MPOLICY scenario. The similarities in the policy effects occur despite disparities in the magnitude of funds flowing into the two countries, respectively 5% and 0.7% of the total amount (equal to 0.3% and 0.7% of their GDP in 2030), as different mechanisms determine this outcome: GCF funds lead to a contraction in the industrial sector share in Nigeria, given that the majority of subsidies are directed to the R&D sector (services), and a shrinkage in the agricultural sector share in Mozambique.

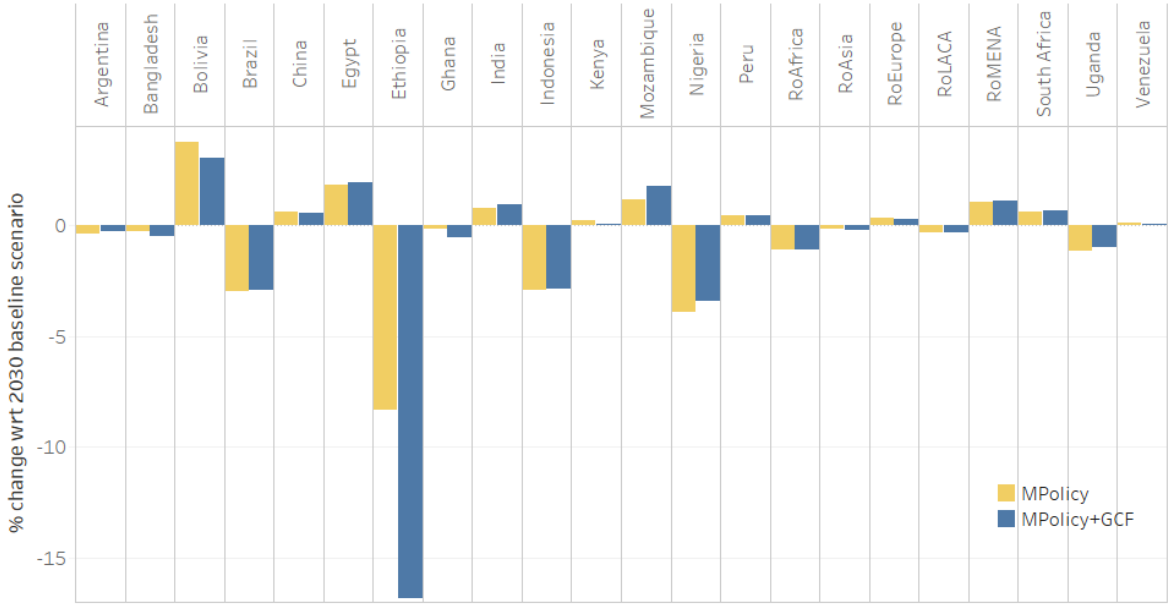


Figure 13 Palma ratio in MPOLICY and MPOLICY+GCF scenarios, %change w.r.t 2030 SSP2 baseline scenario

The MPOLICY+ GCF scenario has an impact on poverty prevalence, altering both the inequality measure and the average per capita income. By 2030, poverty worldwide slightly decreases (-185 thousand poor people) compared to the MPOLICY scenario, with highly heterogeneous outcomes across regions.

The main driver of this impact is the change in per capita GDP that the policy determines. Countries receiving the highest shares from the GCF experience a GDP increase compared to the MPOLICY scenario, which, joined to irrelevant changes in inequality, reduces poverty prevalence in Indonesia (-0.6%), RoAfrica (-0.48%), RoAsia (-0.35%), Brazil (-0.12%) and India (-0.02%).

Conversely, in Bangladesh, Uganda, Ghana and Ethiopia the influx of international funds causes a rise in poverty compared to the MPOLICY scenario (respectively by 1.82,

0.88, 0.73 and 0.44%]. Behind this result is a regressive effect of subsidies on the GDP passing through the trade balance. The support to Clean Electricity and R&D determines a flow of labor and capital towards these sectors that is detrimental to other production sectors (in particular light industry), which see a reduction in output. This also determines a contraction in exports not compensated by a rise in the exportation of Clean Electricity and R&D, whose traded production is limited.

Mozambique and Egypt show an interesting pattern: in spite of a limited influx from the GCF (0.7% and 2.2% of the fund), they experience a substantial drop in poverty prevalence compared to the MPOLICY scenario, namely -2.6% and -1%. For both countries, the rise in per capita income more than compensates a small increase in inequality. The subsidy, especially to Clean Electricity, has a progressive impact on these two economies, stimulating heavy industry production, which is the leading export sector and, therefore, determining an improvement in the trade balance.

Despite the moderate decrease worldwide of poverty prevalence linked to the introduction of the GCF scheme compared to MPOLICY alone, its magnitude remains above the baseline level in 2030 (around 3 million people more than in the baseline scenario).

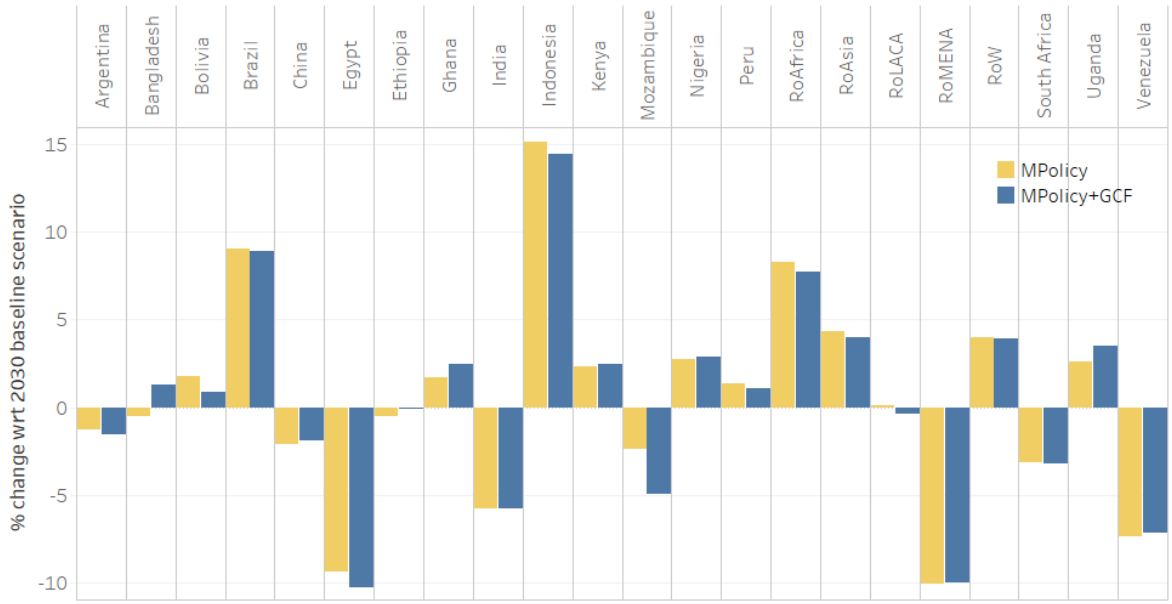


Figure 14 Poverty headcount rate in MPOLICY and MPOLICY+GCF scenarios, %change wrt 2030 SSP2 baseline scenario

Conclusions

Two types of conclusions can be derived from our analysis. First, from a methodological point of view, our study shows that linking empirical social SDG indicators to a CGE model, as in the case of the "Poverty headcount ratio" and the "Palma ratio," makes possible a coherent assessment of future trends of these indicators under different scenarios and policy interventions.

Second, the output of our analysis makes an important contribution to the literature on the linkages between climate change policy and sustainable development, and makes it possible to formulate policy recommendations that inform the ongoing debate on the implementation of the Paris Agreement and the Green Climate Fund.

In particular, if we consider the full implementation of the emission reduction contributions stated in the NDCs, and take into account only the cost side of mitigation policy, the Paris Agreement is projected to slow down poverty reduction compared to the reference scenario. Despite the heterogeneity of results, the effect is stronger for countries that proposed a relatively more stringent mitigation component in their NDC, whereas countries with a loose mitigation target are likely to experience lower policy costs and a consequent competitive advantage. However, the aggregate effect of current NDCs on poverty headcounts is not so broad, accounting for an increase of 2% globally in 2030 compared to the baseline scenario. Conversely, countries with relatively more stringent mitigation policies show a decline in inequality compared to the baseline scenario levels. This would suggest potential synergies between climate change interventions and the income increase in the poorest strata of the population.

By introducing the possibility of distributing a portion of carbon revenues through a Green Climate Fund to support developing countries we can infer some implications for both the donor and the recipient countries. Specifically, by assuming an equal share of proceeds from the ETS or carbon tax among developed countries, the maximum amount of revenues they are required to donate to reach the pledged funds is 7% in 2020, after which the burden starts to decrease. In most developing countries that receive international financial support in the form of sector-specific subsidies, it accelerates poverty reduction efforts compared to the mitigation scenario with internal recycling of revenues. In big recipient countries, the funds lead to a GDP increase and a consequent reduction in poverty prevalence. However, some of the least developed countries show a regressive effect of subsidies to Clean Electricity and R&D, which, by

attracting resources, are detrimental to other production sectors, which in turn experience a reduction of output and a contraction of exports. Mozambique and Egypt show interesting results: in spite of a limited influx from the Fund, they experience a consistent drop in poverty prevalence due to the subsidy, especially to Clean Electricity, which stimulates one of the leading export sectors, i.e. heavy industry, and, therefore, determines an improvement in the trade balance. Worldwide, in the MPOLICY+GCF scenario poverty slightly decreases (-185 thousand poor people) even though the magnitude does not manage to offset the increase experienced in the MPOLICY scenario.

Overall, we observe that the relative magnitude of funds flowing into beneficiary countries is a crucial factor in making the international climate transfers a pro-poor instrument, as it is more likely to observe a reduction in poverty in countries that receive a higher amount of funds proportional to the size of their economy. Therefore, the allocation scheme matters for determining the final outcome on poverty prevalence.

However, it is worth emphasizing that its major purpose is to spread good practices and technologies for mitigation and adaptation, and it should therefore be considered as additional to traditional funds for tackling other sustainable development targets. Nevertheless, our results would suggest the need to prioritize policies that jointly address climate change mitigation and socio-economic development. In addition, our results make a strong case for the creation of a new effective mechanism that will contribute to mitigating greenhouse gas emissions and supporting sustainable development, as stated in Article 6.4 of the Paris Agreement.

Crucially, it should be recalled here that these results probably overestimate the negative effect of mitigation on poverty and inequality because our framework does not consider the benefits connected to reduced climate change impacts, which will be addressed in future research. As a consequence, these results must be judged with caution: although it is reasonable to think that climate policy per se and its cost will imply a slight increase in poverty prevalence, if we also take into account the benefits of avoided climate-induced impacts, we very likely will find a reversal of the results in favour of a poverty reduction in both mitigation scenarios.

Acknowledgments

The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/ under REA grant agreement number 609642.

The research is an output of "Climate Change Economic Impacts and Adaptation" (EIA) Research program and part of FEEM cross-cutting research theme "Agenda 2030".

Notes

A previous version of this essay was published as FEEM Working Paper 2017.048. It is co-authored with Campagnolo Lorenza.

References

Aldy, J., Pizer W., Tavoni M., Aleluia Reis L., Akimoto K., Blanford G., Carraro C., Clarke L.E., Edmonds J., Iyer G.C., McJeon H.C., Richels R., Rose S., Sano F., 2016. "Economic Tools to Promote Transparency and Comparability in the Paris Agreement." Nature Climate Change 6 (11) (August 22): 1000–1004. doi:10.1038/nclimate3106.

Alvaredo F. and Gasparini L., 2015. "Recent trends in inequality and poverty in developing countries", in: Atkinson A.B. and Bourguignon F. (eds), "*Handbook of Income Distribution*", Volume 2A, 2015 Elsevier B.V.

Beg, N., Morlot, J.C., Davidson, O., Afrane-Okesse, Y., Tyani, L., Denton, F., Sokona, Y., Thomas, J.P., La Rovere, E.L., Parikh, J.K., Parikh, K., Rahman, A.A., 2002. Linkages between climate change and sustainable development. Climate Policy 2, 129–144. doi:10.3763/cpol.2002.0216

Boccanfuso D., Decaluwé B. and Savard L., 2003. "Poverty, Income Distribution and CGE Modeling: Does the Functional Form of Distribution Matter?". *Centre interuniversitaire sur le risque, les politiques économiques et l'emploi* Cahier de recherche/Working Paper *03-32.*

Bohringer C. and Löschel A., 2006. "Computable general equilibrium models for sustainability impact assessment: Status quo and prospects". Ecological Economics, 60, issue 1, p. 49-64.

Bourguignon F. and Morrisson C., 1998. "Inequality and development: the role of dualism". *Journal of Development Economics*, 57: 233–257.

Bourguignon F., Ferreira F. and Lustig N., 2005. "The Microeconomics of Income Distribution Dynamics in East Asia and Latin America". World Bank report, Washington, DC.

Büchs M., Bardsley N., Duwe S., 2011. Who bears the brunt? Distributional effects of climate change mitigation policies. *Critical Social Policy*, 31, (2), 285-307 doi:10.1177/0261018310396036

Bussolo M. and Lay J., 2003. "Globalisation and poverty changes in Colombia". *OECD* Working paper No. 226.

Callan T., Lyons S., Scott S., Tol R.S.J., Verde S., 2009. "The distributional implications of a carbon tax in Ireland". Energy Policy, Volume 37, Issue 2, Pages 407-412,

Clarke L., Edmonds J., Krey V., Richels R., Rose S. and Tavoni M., 2009. International climate policy architectures: Overview of the EMF 22 International Scenarios. *Energy Econ*. 31, Supplement 2:S64–81

Cobham A. and Sumner A., 2013. "*Putting the Gini Back in the Bottle? "The Palma" as a Policy-Relevant Measure of Inequality*". King's College London

Dennig F., Budolfson M. B., Fleurbaey M., Siebert A. and Socolow R. H., 2015. "Inequality, climate impacts on the future poor, and carbon prices". PNAS 2015 112 (52) 15827-*15832*

Eboli F., Parrado R. and Roson R., 2010. "Climate Change Feedback on Economic Growth: Explorations with a Dynamic General Equilibrium Model". Environment and Development Economics Volume 15 (5) pp 515 -533

Ferreira F.H.G., Leite P.G. and Ravallion M., 2010. "Poverty reduction without economic growth?: Explaining Brazil's poverty dynamics, 1985-2004". *Journal of Development Economics*, 93(1): 20-36.

GCF – Green Climate Fund, 2014. "Decisions of the Board – Sixth Meeting of the Board, 19-21 February 2014", GCF/B.06/18, 17 April 2014, agenda item 11 (pag.4). https://www.greenclimate.fund/documents/20182/24940/GCF_B.06_18_-_Decisions_of_the_Board_-_Sixth_Meeting_of_the_Board__19-

21_February_2014.pdf/0ba2bfb2-9cbe-41e1-83a6-c5d5662fb463 (accessed March 10, 2017)

Goulder L.H. 2013. Climate change policy's interactions with the tax system. Energy Economics, Volume 40, Supplement 1, December 2013, Pages S3–S11

Grottera C., Pereira A.O.J. and La Rovere E.L., 2017. "Impacts of carbon pricing on income inequality in Brazil". Journal Climate and Development, Volume 9, 2017 - Issue 1

Heltberg R., 2002. "The poverty elasticity of growth, WIDER Discussion Papers". *World Institute for Development Economics (UNU-WIDER)* working paper No. 2002/21

Hertel T., Verma M., Ivanic M. and Rios A., 2011. "GTAP-POV: A Framework for Assessing the National Poverty Impacts of Global Economic and Environmental Policies. *GTAP* Technical Paper No. 31.

Hilderink H., Lucas P. and Kok M., 2009. "Beyond 2015: Long-term development and the Millennium Development Goals". *Netherlands Environmental Assessment Agency (PBL)*.

Hussein Z., Hertel T. and Golub A., 2013. Climate Change Mitigation Policies and Global Poverty. *Environmental Research Letters* doi:10.1088/1748-9326/8/3/035009.

Jakob M., and Steckel J.K., 2014. "Climate change mitigation could harm development in poor countries". WIREs Climate Change 5: 161–168. doi:10.1002/wcc.260.

Lofgren H., Cicowiez M. and Diaz-Bonilla C., 2013. "A Computable General Equilibrium Model for Developing Country Strategy Analysis", in Dixon P. and Jorgenson D. (eds.), *Handbook of Computable General Equilibrium Modeling*.

van der Mensbrugghe D., 2015. "Shared Socio-Economic Pathways and Global Income distribution". Conference paper *18th Annual Conference on Global Economic Analysis*, 17-19 June 2015, Melbourne, Australia.

Montalvo J.G. and Ravallion M., 2010. "The pattern of growth and poverty reduction in China". *Journal of Comparative Economics*, 38: 2–16.

Narayanan G., Badri Angel Aguiar and Robert McDougall, (Eds), 2012. Global Trade, Assistance, and Production: The GTAP 8 Data Base, Center for Global Trade Analysis, Purdue University

Olsson, L., Opondo M., Tschakert P., Agrawal A., Eriksen S.H., Ma S., Perch L.N., and Zakieldeen S.A., 2014. "Livelihoods and poverty". In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 793-832.

O'Neill B.C., Kriegler E., Ebi K.L., Kemp-Benedict E., Riahi K., Rothman D.S., van Ruijven B.J., van Vuuren D.P., Birkmann J., Kok K., Levy M. and Solecki W., 2017. The roads ahead: narratives for Shared Socioeconomic Pathways describing world futures in the 21st century, Global Environ. Change, Vol.42 pp. 169 – 180 http://dx.doi.org/10.1016/j.gloenvcha.2015.01.004

Rao S., Klimont Z., Leitao J., Riahi K., van Dingenen R., Aleluia Reis L., Calvin K., Dentener F., Drouet L. and Fujimori S., 2016. "A multi-model assessment of the co-benefits of climate mitigation for global air quality". Environmental Research Letters, Volume 11, Number 12

Ravallion M., 1997. "Can high-inequality developing countries escape absolute poverty?". *Economics Letters*, 56: 51-57

Ravallion M., 2001. "Growth, Inequality and Poverty: Looking Beyond Averages". *World Development*, 29(11): 1803-1815.

Ravallion M., 2003. "Inequality convergence". *Economics Letters*, 80: 351–356.

Ravallion M., 2013. "How Long Will it Take to Lift One Billion People Out of Poverty?". World Bank Research Observer Volume 28, Issue 2 Pages: 139 - 158

Ravallion M., 2014. "Income inequality in the developing world". *Science*, 344(6186): 851-855.

Ravallion M., and Chen S.1997. "What Can New Survey Data Tell us about Recent Changes in Distribution and Poverty?". The *World Bank* Economic Review, 11: 357-382.

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C.

Robledo Abad, A. Romanovskaya, F. Sperling and Tubiello F., 2014. Agriculture, Forestry and Other Land Use (AFOLU). In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

von Stechow C., McCollum D.,Riahi K., Minx J.C., Kriegler E., van Vuuren D.P., Jewell J., Robledo-Abad C., Hertwich E., Tavoni M., Mirasgedis S., Lah O., Roy J., Mulugetta Y., Dubash N.K., Bollen J., Ürge-Vorsatz D. and Edenhofer O., 2015. Integrating global climate change mitigation goals with other sustainability objectives: a synthesis. Ann. Rev. Environ. Res. 40, 363–94, https://doi.org/10.1146/annurev-environ-021113-095626

von Stechow C., Minx J.C., Riahi K., Jewell J., McCollum D.L., Callaghan M.W., Bertram C., Luderer G. and Baiocchi G., 2016. 2 °C and SDGs: united they stand, divided they fall?. Environ. Res. Lett. 11, 034022, doi:10.1088/1748-9326/11/3/034022

Steckel J.C., Brecha R.J., Jakob M., Strefler J., Luderer G., 2013. "Development without energy? Assessing future scenarios of energy consumption in developing countries", Ecological Economics, Volume 90, June 2013, Pages 53-67, ISSN 0921-8009, http://doi.org/10.1016/j.ecolecon.2013.02.006.

Swart, R., Robinson, J. and Cohen, S., 2003. Climate change and sustainable development: expanding the options. *Climate Policy* 3, S19–S40. doi:10.1016/j.clipol.2003.10.010

United Nations, 2015. "*Resolution adopted by the General Assembly on 25 September 2015" A/RES/70/1. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E*

United Nations, 2016. "*Report of the Inter-agency and Expert Group on Sustainable Development Goal Indicators", Economic and Social Council, E/CN.3/2017/2. http://unstats.un.org/unsd/statcom/48th-session/documents/2017-2-SDG-IAEG-EE.pdf*

UNFCCC, 2015. Adoption of the Paris Agreement, Paris: UNFCCC Conference of the Parties.Twenty-first session Paris, 30 Nov. to 11 Dec. 2015.

World Bank, 2016. World Development Indicators, 1960 – 2015, available at: http://data.worldbank.org/data-catalog/world-development-indicators

WRI, 2016. CAIT Data Explorer, Washington, DC: World Resources Institute. Available at: http://cait.wri.org/

The role of the Green Climate Fund in financing mitigation action: an impact assessment of different allocation schemes

Introduction

The Green Climate Fund (GCF) is one of the key dedicated institutions aimed at supporting the international community in fulfilling its global climate financing commitments.

It was initially mentioned in 2009 within the Copenhagen Accord, as one of the tools through which part of the USD 100 billion per year by 2020, pledged by the advanced economies, should be distributed to developing ones. One year later, at COP 16 in Cancun, Mexico, the Fund was formally established under the UNFCCC guidance, and it will continue to play its role also within the context of the Paris Agreement.

The GCF objective is to 'promote the paradigm shift towards low emission and climate-resilient development pathways by providing support to developing countries to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change' (GCF, 2011). To make the Fund operative, since 2011 a set of rules was agreed for initial resource mobilization and allocation. In particular, both developed and developing countries can contribute to funding, with the former required to take the lead. Contribution from city and regional authorities are also welcome, while the participation of private sector actors is encouraged. All developing country Parties to the UNFCCC are eligible to receive resources, which are distributed according to project-based and programmatic approaches and through national, regional and international accredited implementing entities (GCF, 2011).

For the initial allocation of resources, the following main rules have been established, in accordance with the UNFCCC guidelines (GCF, 2014):

- To aim at a 50:50 balance between mitigation and adaptation over time.

- To aim at devoting 50% of the adaptation allocation to particularly vulnerable countries, including least developed countries (LDCs), Small Island developing States (SIDS) and African States.

- To seek geographic balance and a reasonable and fair allocation across a broad range of countries, while maximizing the scale and transformational impact of the mitigation and adaptation activities of the Fund;

- To provide sufficient resources for readiness and preparatory support.

At the practical level, the Fund, so far, has been able to raise pledges for USD 10.3 billion equivalent from over 40 contributing countries. Major donors are United States, Japan, United Kingdom, France and Germany. Resource allocation started in 2015. Since then the GCF has approved USD 2.2 billion in co-investment projects across over 60 developing countries, leveraging a total of USD 7.3 billion of private and public funds. Resources have been distributed through 43 projects, estimated to reduce emissions by 978 million ton and to impact 128 million people's life (GCF, 2017).

The impacts of climate finance mechanisms

The reasons for providing climate change support to developing countries are others than those at the base of traditional development aid. In line with the CBDR-RC principle included in the UNFCCC and their crucial contribution to the GHG emission increase, industrialized countries have the obligation to support developing nations both in implementing their own mitigation plans and protecting themselves from the negative consequences of climate change (article 4.3 UNFCCC, 1992).

The role of climate finance mechanisms is therefore crucial in supporting the achievement of global long-term climate goals, as they have the potential to transfer significant financial resources to developing countries and help them reducing the costs of mitigation and adaptation actions (Nakhooda, et al., 2014; Nelson & Shrimali, 2014; Stern, 2007; Markandya, et al., 2015). In addition, investments channelled through the climate-dedicated funds, by deploying low-carbon and adaptation technologies or supporting the creation of national carbon pricing schemes, can give a boost to greener economic sectors and overall arise important development opportunities (Steckel, et al., 2016). For these reasons, climate finance is often considered an opportunity to reconcile equity with effectiveness and efficiency in the climate change action (World Bank, 2009).

Analytical efforts so far have mainly focused on the quantification of climate finance resources and needs (Buchner, et al., 2015; OECD, 2015; Bowen, et al., 2017) as well as on the identification of instruments able to rise and canalize monetary flows (Hof, et al., 2011; Falconer & Wilkinson, 2015; Silverstein, 2011). A limited number of studies focuses on the economic impacts of climate financial transfers from a macro perspective. Among them, Mattoo et al. (2009) and Jakob, et al. (2015) warn against the potential negative effects of both market and non-market financial transfer mechanisms, driven in particular by a Dutch disease-type mechanism[19], which can magnify the adverse effects, or reduce the benefits, of emissions reduction policies on manufacturing output and exports in emerging and developing countries (Mattoo, et al., 2009).

The advent of the GCF in the recent international climate change policy arena, fostered a new debate on its design as well as on the effect on both donor and recipient countries (Bird, et al., 2011; van Kerkhoff, et al., 2011; Sierra, 2011; Carraro & Massetti, 2012; Vieweg, 2013; Cui, et al., 2014; Fridahl & Linnér, 2015; Markandya, et al., 2015; Mathy & Blanchard, 2016; Antimiani, et al., 2017). With respect to the allocation of resources, that is this essay's subject, literature focuses mainly on the GCF contribution in terms of emission reduction potential in developing countries while rather fewer studies consider the economic impact of different allocation options. As for the first matter, Carraro & Massetti (2012), for example, model different combinations of mitigation pledges and international funds to understand the abatement potential impact of the GCF on 2020 emissions. Overall, they find that international transfers aimed at financing mitigation can unlock a number of cheap options (<$50 per tonne CO2-eq, mainly in REDD and power sectors) and therefore substantially reduce emissions, especially in China and Latin America, where major abatement opportunities are concentrated. Using the Copenhagen pledges as a reference, the authors estimate that additional 2.5 Gt CO2-eq of abatement in 2020 can be covered by 50% of the GCF in case the upper level of commitments is undertaken, to decrease to 25% for lower commitments (Carraro & Massetti, 2012). Cui et al. (2014) reaches similar conclusions for the 2030 time horizon. They investigate two approaches to allocate money for mitigation in developing countries, according

[19] According to Strand (2009), there is a "Dutch disease" effect when "increased financial inflows lead to an appreciating exchange rate, productivity/profitability in export and import substitution industries are adversely affected, thus hampering their development".

respectively to the ambition of the action (i.e. 'carbon reduction contribution') and to the marginal cost (i.e. 'incremental cost')[20]. Their findings show that the USD 100 billion may induce significant emission reduction between emerging and developing countries, especially in the case of the incremental cost approach. Minimal differences emerge from the two distribution methods, with China attracting the greatest share of inflows (about 30%) because of its large abatement potential. India manages to gather about 10% of the funds while the Africa's low abatement potential led the continent to obtain no more than 8% (Cui, et al., 2014).

Closer to our focus, Markandya, et al. (2015) use a dynamic CGE model to assess the potential of alternative GCF allocating options in decreasing mitigation costs. In particular, they consider an emission scenario consistent with the goal of limiting the increase in global temperature to 2°C by 2100 complemented by a GCF and an International Emission Trading (IET) system. They assume international climate transfers are distributed to developing countries according to: i) their GDP share, ii) their vulnerability to climate impacts, and iii) their (in)ability to react to climate impacts. Developing countries can use the financial inflows for welfare purposes or to incentivize different technology mixes (energy efficiency and/or renewable sources). Overall, the authors point out that financial transfers can be beneficial for both donors and recipient countries. Their estimates show, indeed, that the developed countries' contribution to GCF does not exceed the 0.5% of GDP over the period 2015–35 and is even lower when money is spent through the technological options. This happens because the developing countries' investment in the selected energy technologies, and especially in energy efficiency, reduces the overall abatement costs and consequently the carbon price needed to reach the stabilization objective. Interestingly, benefits for less developed economies are also significant, as through the GCF used to incentivize technology, the welfare losses associated with the climate policy are substantially reduced. Of course, the effect on single countries is heterogeneous mainly because the size of technological opportunities depends on the structural features of the economy.

Against this background, the way resources are allocated to recipient countries undoubtedly arises as a crucial factor influencing the direction of the impact financial flows can lead to. For this reason, we aim at enriching the debate by estimating the

[20] For the purpose of this paper we focus only on options for mitigation. Cui et al. (2014) propose also an approach based on regional adaptation needs.

effect of international climate finance support in the context of the Paris Agreement, and in particular considering the emission reduction objectives proposed by both developed and developing countries through the NDCs.

Modelling design and scenarios

The Nationally Determined Contributions (NDC) submitted by both developed and developing countries under the Paris Agreement are the starting point of our analysis. We compute the cost of achieving national emission reduction targets stated within the NDCs in 2030 against a baseline scenario that projects socio-economic and population dynamics similar to those observed in recent decades (SSP2, the so-called "Middle of the Road" scenario, as in O'Neil et al. 2017). For this purpose, all countries with the exception of the UE28, achieve the conditional abatement target stated in their NDC through the implementation of a national carbon tax. Instead, in the EU28, the Emission Trading System allows Member States to achieve an efficient level of carbon reduction.

The role of GCF is then assessed in terms of cost reduction and incentive to clean energy technologies in developing countries. To do so, we use the actual allocation rules adopted by the Green Climate Fund to design a fund able to achieve an "equal balance between adaptation and mitigation", as well as a "geographic balance and a reasonable and fair allocation across a broad range of countries" (GCF, 2014). Since, for the moment, we consider only the support to mitigation actions, the fund is planned to reach $50 billion (US$2007) in 2020 (50% of the pledged $100 billion a year by 2020) and then remain constant. The countries contributing to the fund are those that actually expressed a pledge within the GCF, and participate to the overall effort according to their current share of contribution (GCF, 2017).

The recipient countries are selected among less developed nations, according to the following approach: up to 2020 countries that are already receiving financial support from the GCF, after 2020 all developing countries excluding China. The funds are then distributed across beneficiary countries on the base of different allocation schemes devoted to finance different low-carbon options (Figure 15). In particular, the distribution of the GCF inflows is proportional to two alternative options: the population share (GCF allocation I) or the losses induced by the mitigation action (GCF allocation II).

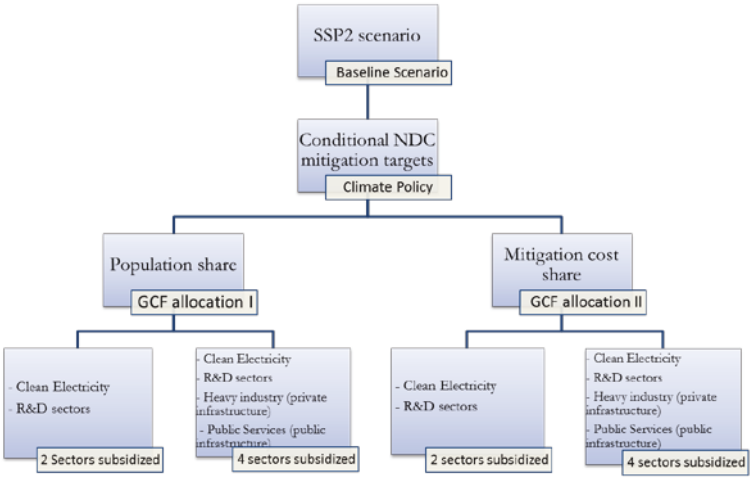


Figure 15: Policy scenario scheme

For each option, we foresee two possible investment schemes by developing countries: GCF inflows are used to subsidize 2 sectors, namely Clean Electricity and R&D or are split among 4 sectors including also Heavy industry and Public Services. This latter case aims at investigating the effect of initially subsidizing sectors connected to the development of private and public infrastructures as a necessary leverage for mitigation efforts. The importance of strengthening infrastructures for a more effective mitigation action is evident especially in Africa (Mutanga, et al., 2017).

Donors and recipients

One of the first interesting results we can infer from our analysis is the distribution of the financial burden among donor countries. Figure 16 shows the contribution shares that currently fuel the GCF and that we assume will remain constant up to 2030. Major donors, among single countries, are the United States, whit about 30% of the total amount, followed by Japan and the major European countries. However, when the EU is considered as a single entity, its contribution is the largest, accounting for around 47% of the total. Among the most generous Member States emerge the UK, which contributes with 12% of the global amount, France and Germany (about 10% respectively). Smaller financial flows are provided by Australia and Canada, which reach 2 and 3%, respectively.

Although major emitters contribute the most, these figures diverge slightly from the shares estimated by the literature. For example, according to Cui, et al. (2014), which

estimated an allocation method based on environmental responsibility and economic capacity, the US should contribute with a higher effort to reach about 43% of the total sum. On the contrary, the actual financial flows provided by both the EU and Japan represent even a higher share than their estimated equitable portions (41 and 9%), whereas Canada and Australia's quota are in line with Cui et al. (2014)'s findings.

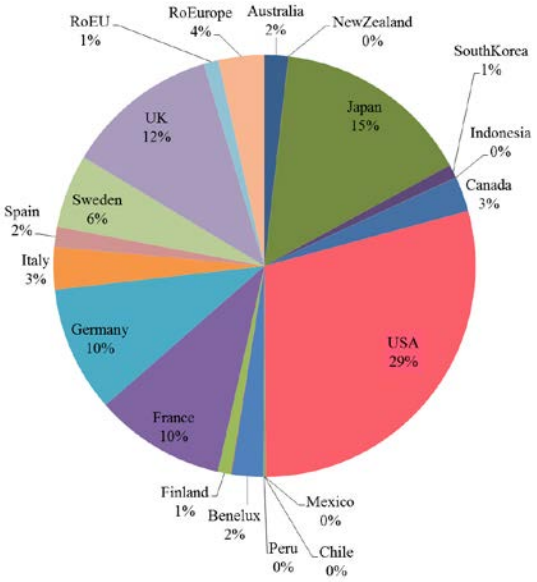


Figure 16: Country's contribution to GCF

Focusing on countries that receive financial support through the GCF, Figure 17 clearly illustrates that funds flow to different countries under the two alternative distribution schemes. In particular, India, RoAsia, RoAfrica, RoMENA, Indonesia and Nigeria collectively attract 71% of the financial support under the population-based distribution (Allocation I). Under the allocation based on GDP losses (Allocation II), the majority of resources are distributed among a fewer number of beneficiary countries, with Indonesia, Brazil, RoAfrica, Mexico and RoW gathering 90% of the total funding. Interestingly, the projected GDP losses driven by the implementation of the NDCs[21] in Brazil, Indonesia and Mexico allow them to obtain a substantially larger share of the US$ 50 billion fund with the second allocation method. Conversely, countries with an estimated less costly (and ambitious) mitigation objective manage to receive more funds if the criterion of population size is preferred. This is especially the case of India and the MENA region that, while receiving a significant share of inflows with the first allocation, are completely outside the distribution when the second method is applied.

[21] For the impact of NDCs on GDP please refer to Figure 8 chapter 4.

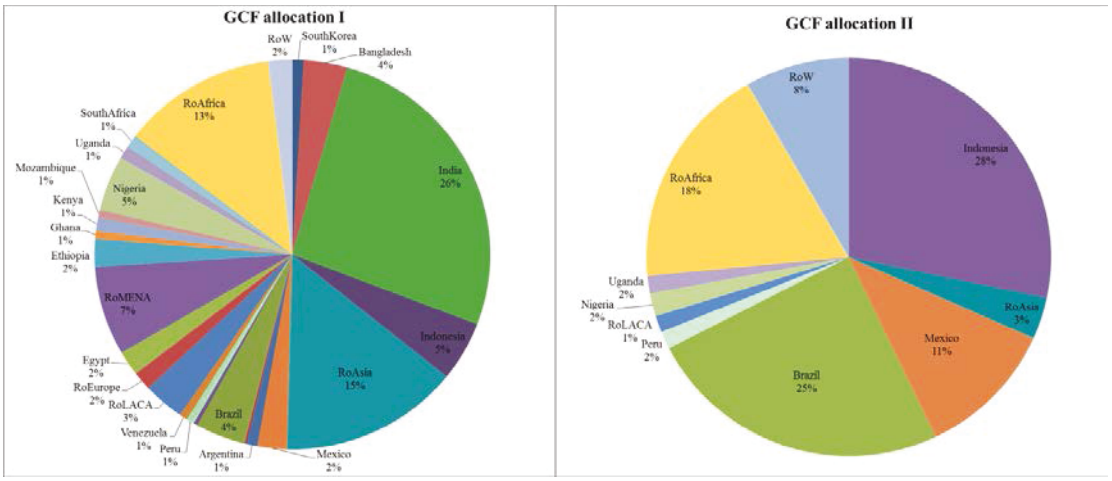


Figure 17: Recipient countries in 2030: GCF allocation I and II

What are the major implications of the allocation schemes?

This section analyses the effects of the two different allocation schemes chose to distribute the US$50 billion (US$2007) to developing countries. Main results are summarized in Figure 18, which compares the changes in 2030 GDP of the climate policy scenario with the introduction of inflows from the GCF allocated according to the two alternative schemes. In both allocations, money transferred from the fund is channelled towards two "mitigation" sectors, i.e. Clean Electricity and R&D by means of an output subsidy. Its initial distribution is equal across sectors: half of the fund goes in subsidizing Clean Electricity and the other half goes to R&D; these shares converges respectively to 90% and to 10% in 2030.

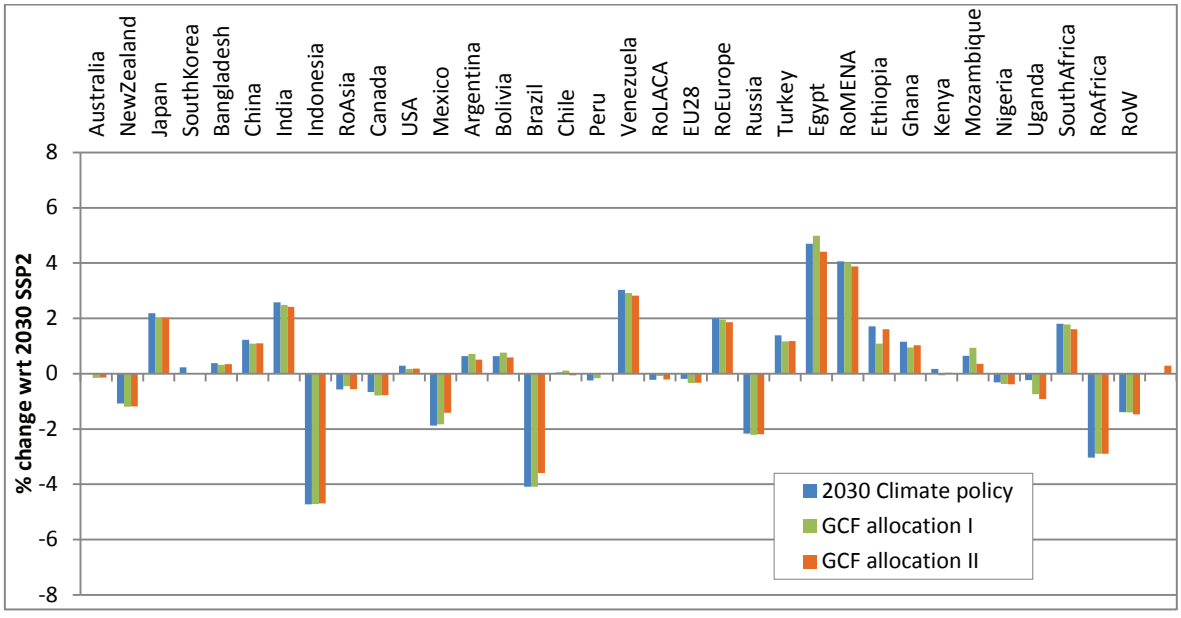


Figure 18: GDP % change compared to 2030 baseline

Even with some exceptions, it is possible to disentangle some broad effects of the international climate inflows transfer on both donors and recipient countries. In general, donor countries, by recycling their carbon tax revenues to finance an international fund and not internally, are slightly worse off. On the contrary, recipient countries experience economic benefits form the GCF inflow (especially in the GCF Allocation II that split the fund to a reduced number of beneficiaries); the magnitude of GCF inflow seems to be a key element for the outcome of the policy, but it is not sufficient. In many cases, the economic structure matters the most.

Under the GCF allocation I, Latin America (excluding Venezuela) is better off compared to the mitigation scenario. The money inflows, redistributed via sectoral subsidies, stimulate targeted sectors but have also an expansive effect on industrial and service sectors, favouring investment and capital accumulation. These components more than compensate the worsening in the trade balance due to exports shrinking more than imports. In Venezuela, this reinforcing effect does not take place and, conversely, Clean Electricity and R&D subtract capital and labour resources from other sectors, reducing their output and the capital accumulation of the economy.

In Asia and Africa, the GCF (Allocation I) seems less effective to stimulate economic growth and coincides in many cases with a contraction of exports (the boom of exports of clean electricity is irrelevant in magnitude compared to the slight decline of exports of light and heavy industries, and processed food) and it is not completely offset by higher consumption and investments. This is true also when the inflow from the GCF is conspicuous: in Ethiopia the received funds account for 1.10% of the GDP, but the gain of 1.71% under the mitigation policy shrinks to 1.08%. In this case, the contraction of exports is combined to a reduced output in agricultural and service sectors due to the reallocation of a portion of capital towards subsidized sectors. Uganda, passing from -0.24 to -0.74% GDP despite a transfer equal to 0.99% of its GDP, shows a similar pattern; in spite of a positive impact of the policy on trade balance (more export from agriculture and services), production shrinks especially in heavy and light industry, transport and processed food sectors. Although the large difference in the amount of funding received using the two alternative allocations, no relevant effect of the Fund is detected in Indonesia, while it is very small in India.

Egypt Mozambique and Rest of Africa are an exception in the African continent performance. They receive transfers respectively equal to 0.25, 0.83 and 0.57% of their

GDP and reduce losses by 0.3, 0.3 and 0.2% compared to the mitigation scenario. In Egypt and Rest of Africa the output expansion of subsidised sectors stimulates production of services and heavy industries that more than compensate the contraction of output in light industry.

The GCF Allocation II has a positive effect on most of the countries, but it is worth to notice that recipients are fewer than in the GCF Allocation I. Under GCF Allocation II, Brazil and Mexico, which receive conspicuous transfers, slightly improve their position compared to the mitigation scenario (+0.5% in terms of GDP).This result is due to a steep rise in the output of subsidized sectors, but also on other sectors excluding those directly influenced by the mitigation policy (fossil fuels and electricity). Higher investment and capital accumulation more than offset the negative impact on the trade balance (contraction of export). Uganda, Nigeria and Rest of the World are worse off in both GCF allocation schemes.

As for the effect on clean energy technologies diffusion, less developed countries show some worth noting patterns (Figure 19). In particular, the inflows from the GCF overall increase the already positive effect of the climate policy in spreading renewable energy technologies. This happens in Indonesia, Mexico the Rest of World Peru and the Rest of the African continent, but also in Bangladesh, RoMENA, South Africa, Nigeria, Rest of Asia, Argentina and Chile, where the renewable share over the total electricity share further increases as a consequence of the money inflows toward these sectors. Of course, the differences in the amount received in the two allocations explain the differences in the size of the effect. In India, Bolivia, and Egypt, which receive funds only with the population share allocation criterion, the GCF inflows even manage to reverse the null or negative effect on renewable production induced by a not so stringent mitigation policy. A very small effect is distinguishable in countries where the renewable share is already projected to increase toward the total electricity production in 2030 in the BaU or mitigation policy scenarios. This explains the lack of any deductible change in Mozambique and Uganda as well as the minimal impacts of funds in Ethiopia, Venezuela, Kenya and Brazil.

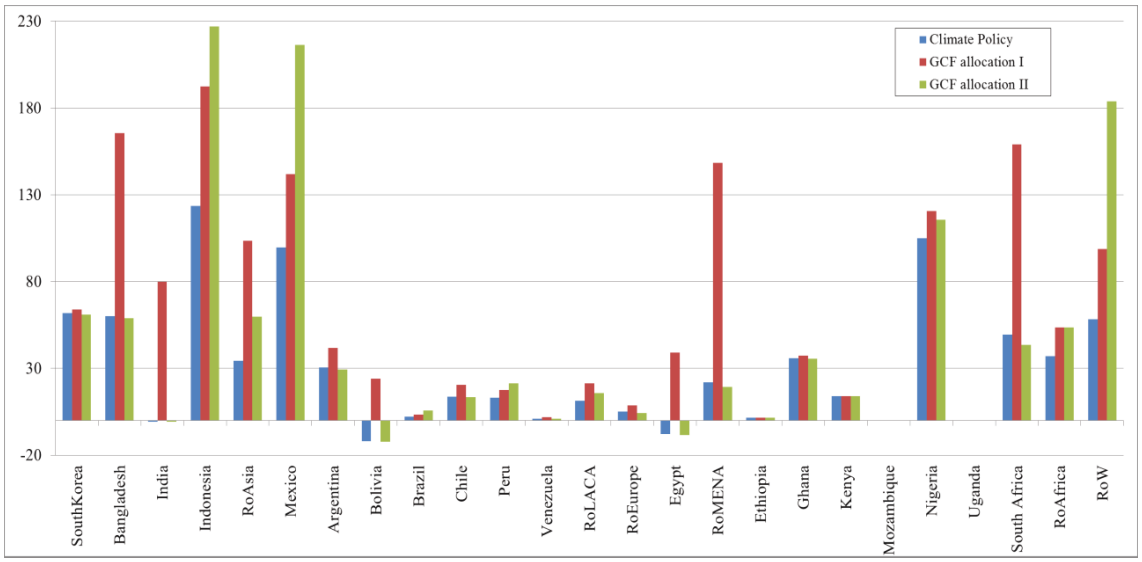


Figure 19: Renewable share over electricity production. Percentage change compared to BaU in 2030

Which sectors to prioritize?

Finally, we simulate a scenario that subsidizes two additional sectors connected to the development of private and public infrastructures as a necessary precondition for mitigation efforts.

The implementation of the mitigation policy is the same as above but the transfers from the GCF to developing countries go to subsidize four sectors (rather than two): i.e. Clean Electricity, R&D, Heavy industry (which includes the construction sector) and Public Services. The initial allocation of funds' share are: Clean Electricity (40%), R&D (20%), Heavy industry (20%) and Public Services (20%); these converge respectively to 80, 10, 0 and 10% in 2030.

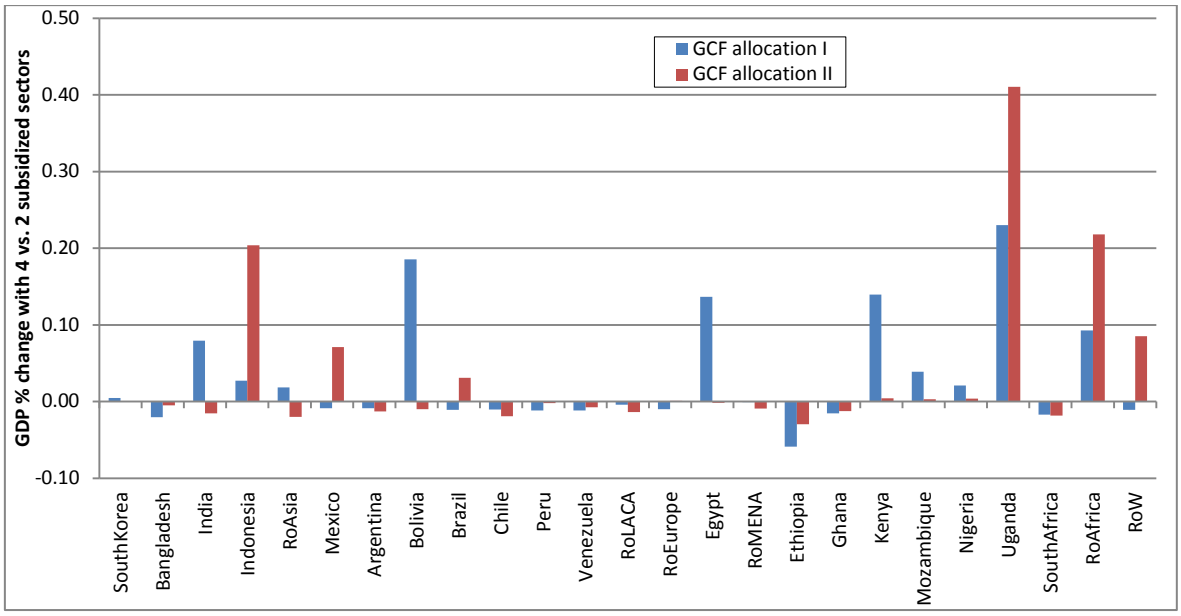


Figure 20: GDP changes in recipient countries in 2030, 4 vs. 2 subsidized sectors

The Figure 20 shows the effect on GDP of the four-sector investment for each of the two alternative allocations compared to the scenarios with only two sectors subsidized.

The importance of strengthening infrastructures for a more effective mitigation action is evident especially in developing Asian and Africa. The largest upsurges in welfare are registered in Uganda and in the Rest of the African region, who see their GDP increasing by 0.23 – 0.41% and 0.1-0.22% respectively. Some smaller but relevant effect is also experienced in Kenya, Mozambique and Nigeria when the share of funds they receive is significant in terms of GDP (Allocation I). An increase is also detectable in Indonesia (0.2% under the allocation II) and in Bolivia (0.19% under the allocation I). The crucial point to consider here is that in least developed countries, where the expansion potential of infrastructures is still relatively large, distributing the international climate transfers also to these sectors can have a larger positive effect on the country's welfare.

Some exceptions however arise, such as Ethiopia, Ghana, South Africa, Bangladesh, Argentina, and the Rest of Latin America. This can be explained by the fact that in these countries the subsidized infrastructure sectors (Heavy Industry and Public Service) are too small to produce significant effects and the economy suffer from the fact that the money is diverted from the more productive clean electricity technologies.

Conclusions

The role of climate finance instruments can be crucial in supporting the achievement of global long-term climate goals. Through them, indeed, less developed countries can receive significant financial support from the more advanced economies to implement their own mitigation and adaptation plans. The Green Climate Fund is therefore emerging as a powerful tool to channel the US$100 billion per year pledged by developed countries under the Paris Agreement.

In this essay, we contribute to the current debate by confronting the actual GCF distribution scheme, based on a geographic balance among the widest number of countries, with an alternative allocation that compensates recipients according to the potential economic losses imposed by the climate policy stated in their NDCs.

Overall, our results show that the two allocation methods prioritize very different countries. When the size of the country's population is taken into account, the number of GCF beneficiaries is wider. In this case, developing countries that are already gaining from a relatively less stringent 2030 mitigation objective further expand their welfare as a consequence of the international inflows to clean energy sectors. On the contrary, distributing the financial support according to economic losses leads the GCF to play an important role in reducing the costs of those countries that are estimated to suffer negative consequences for the implementation of their NDCs.

In addition, the clean energy and R&D sectors show a substantial expansion because of the boost they receive from the international funds, except in the countries where these sectors are already mature and show no further growing potential. When the money is channelled also to infrastructural sectors some further increase in the contribution of GCF to the domestic welfare is detected. However, the effect depends on the initial size of these sectors as well as on the amount channelled through the international financing tools.

Some policy recommendations can be derived by our exercise. First of all, the different distributions coming out from the two allocation methods suggest that, for what mitigation funds are concerned, prioritizing the nations that are proposing more ambitious targets (and therefore supporting higher costs) seems a fairer approach as it would allow them to reduce the cost of the climate action. Although the difficulties in implementing (and accepting) such a solution in the reality, it can also constitute an incentive for developing countries to propose more and more ambitious emissions reduction targets.

In addition, our results also highlight that it would be preferable to follow country-specific opportunities, both in terms of initial energy mix and economic structure, in order to invest in selected emissions reduction sectors that have a larger expansion potential. In this regard, the project-based approach chosen by the GCF, can represent an appropriate choice to unlock country-driven win-win opportunities. On the other hand, providing an initial support through climate finance tools to readiness and capacity building activities can, sometimes, be highly beneficial.

Finally, it is worth recalling that our modelling exercise focuses only on the financial support to mitigation measures. Further beneficial opportunities can certainly arise from the funds that will be devoted to adaptation actions.

References

Antimiani, A. et al., 2017. The Green Climate Fund as an effective compensatory mechanism in global climate negotiations. *Environmental Science & Policy,* Volume 77, pp. 49-68.

Bird, N., Brown, J. & Schalatek, L., 2011. *Design challenges for the Green Climate Fund.Climate Finance Policy Brief No.4,* s.l.: Overseas Development Institute.

Bowen, A., Campiglio, E. & Herreras Martinez, S., 2017. An 'equal effort' approach to assessing the North–South climate finance gap. *Climate Policy,* 17(2), pp. 231-245.

Buchner, B. et al., 2015. *Global Landscape of Climate Finance 2015. A CPI Report,* Climate Policy Initiative.

Carraro, C. & Massetti, E., 2012. Beyond Copenhagen: a realistic climate policy in a fragmented world. *Climatic Change,* Volume 110, p. 523–542.

Cui, L., Zhu, L. & Springmann, M., 2014. Design and Analysis of the Green Climate Fund. *Journal of Systems Science and Systems Engineering,* 23(3), p. 266–299.

Falconer, A. & Wilkinson, J., 2015. *Three tools to unlock finance for land-use mitigation and adaptation,* s.l.: Climate Policy Initiative.

Fridahl, M. & Linnér, B., 2015. Perspectives on the Green Climate Fund: possible compromises on capitalization and balanced allocation. *Climate and Development,* 18(2), pp. 105-109.

GCF, 2011. *Governing Instrument for the Green Climate Fund,* s.l.: Green Climate Fund.

GCF, 2014. *Decisions of the Board – Sixth Meeting of the Board, 19-21 February 2014 GCF/B.06/18,* s.l.: Green Climate Fund.

GCF, 2017. *Green Climate Fund.* [Online] Available at: http://www.greenclimate.fund/what-we-do/portfolio-dashboard [Accessed August 2017].

Hof, A., den Elzen, M. & Mendoza Beltran, A., 2011. Predictability, equitability and adequacy of post-2012 international climate financing proposals. *Environmental Science & Policy,* Volume 14, p. 615 – 627.

Jakob, M., Steckel, J., Flachsland, C. & Baumstark, L., 2015. Climate Finance for Developing Country Mitigation:. *Climate and Development,* 7(1), pp. 1-15.

Markandya, A. et al., 2015. Analyzing Trade-offs in International Climate Policy Options: The Case of the Green Climate Fund. *World Development,* Volume 74, p. 93–107.

Mathy, S. & Blanchard, O., 2016. Proposal for a poverty-adaptation-mitigation window within the Green Climate Fund. *Climate Policy,* 16(6), pp. 752-767.

Mattoo, A., Subramanian, A., van der Mensbrugghe, D. & He, J., 2009. *Can Global De-Carbonization Inhibit Developing Country Industrialization? CGD Working Paper 188,* Washington, D.C.: Center for Global Development.

Mutanga, S., Quitzow, R. & Steckel, J., 2017. *The G20's role in improving quality of life through sustainable energy and urban infrastructure in Africa,* s.l.: G20 Insights .

Nakhooda, S. et al., 2014. *Climate finance: is it making a difference?,* s.l.: Overseas Development Institute.

Nelson, D. & Shrimali, G., 2014. *Finance Mechanisms for Lowering the Cost of Renewable Energy in Rapidly Developing Countries,* s.l.: A CPI Series, Climate Policy Initiative.

O'Neill, B. et al., 2017. The roads ahead: narratives for Shared Socioeconomic Pathways describing world futures in. *Global Environmental Change,* Volume 42, p. 169 – 180.

OECD (2015), "Climate finance in 2013-14 and the USD 100 billion goal", a report by the Organisation for Economic Co-operation and Development (OECD) in collaboration with Climate Policy Initiative (CPI). [Online] Available at http://www.oecd.org/environment/cc/OECD-CPI-Climate-Finance-Report.pdf

Sierra, K., 2011. *The Green Climate Fund: Options for Mobilizing the Private Sector,* London, UK: Climate and Development Knowledge Network.

Silverstein, D., 2011. Using a harmonized carbon price framework to finance the Green Climate. Fund.

Steckel, J. et al., 2016. From climate finance towards sustainable development finance. *WIREs Climate Change,* 8(1).

Stern, N., 2007. *The Economics of Global Climate Change: The Stern Review.* Cambridge, UK: Cambridge University Press.

Strand, J., 2009. *Revenue Management Effects Related to Financial Flows Generated by Climate, WB Policy Research Paper 5053,* Washington D.C.: The World Bank.

van Kerkhoff, L., Ahmad, I., Pittock, J. & Steffen, W., 2011. Designing the Green Climate Fund: how to spend $100 billion sensibly. *Environment: Science and Policy for Sustainable Development,* 53(3), pp. 18-31.

Vieweg, M., 2013. *Options for Resource Allocation in the Green Climate Fund (GCF). Possible Allocation Principles and Criteria – Mitigation,* s.l.: Climate Analytics.

World Bank, 2009. Generating the Funding Needed for Mitigation and Adaptation. In: *World Development Report 2010.* Washington DC, USA: The World Bank, p. 257–285.

Appendix I

ICES is a recursive- dynamic multiregional Computable General Equilibrium (CGE) model developed to assess impacts of climate change on the economic system and to study mitigation and adaptation policies. The model's general equilibrium structure allows for the analysis of market flows within a single economy and international flows with the rest of the world. This implies going beyond the "simple" quantification of direct costs, to offer an economic evaluation of second and higher-order effects within specific scenarios either of climate change, climate policies or different trade and public-policy reforms in the vein of conventional CGE theory.

The core structure of ICES derives from the GTAP-E model (Burniaux and Troung, 2002), which in turn is an extension of the standard GTAP model (Hertel, 1997). The General Equilibrium framework makes it possible to characterise economic interactions of agents and markets within each country (production and consumption) and across countries (international trade).

Within each country the economy is characterised by n industries, a representative household and the government. Industries are modelled as representative cost-minimizing firms, taking input prices as given. In turn, output prices are given by average production costs. The production functions (Figure A1) are specified via a series of nested Constant Elasticity of Substitution (CES) functions that combine primary factors (natural resources, land, and labour), a Capital+Energy composite, and intermediates, in order to generate the output. To all intermediates apply the "Armington assumption" that introduces some frictions on the substitutability of inputs imported from different countries.

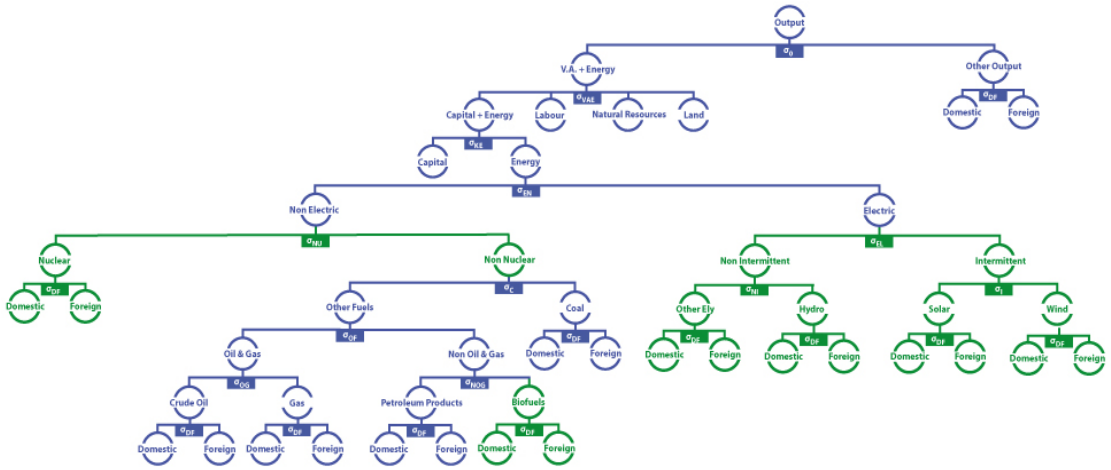


Figure A1 - ICES production tree

As well as in GTAP-E model, the specification of Energy nest is detailed considering electricity and several fossil fuels (coal, oil, gas and petroleum products). ICES model further specifies renewable energy sources in electricity production, namely wind, solar and hydro-electricity, splitting them from the original electricity sector. The data collection refers to physical energy production in Mtoe (Million tons of oil equivalent) from different energy vectors and for each GTAP 7 country/region. The data source is Extended Energy Balances (both OECD and Non-OECD countries) provided by the International Energy Agency (IEA). We complemented the production in physical terms with price information (OECD/IEA 2005; Ragwitz et al. 2007; GTZ 2009; IEA country profiles and REN21).

Figure A2 describes the main sources and uses of regional income. In each region, income is detained by private household and government income; for the former agent, income corresponds to the service value of national primary factors (natural resources, land, labour, and capital), for the latter one, it equals to the total tax revenues from both private household and productive sectors, a series of international transactions among governments (foreign aid and grants) and national transfers between the government and the private (Delpiazzo et al., 2017). Both the government and the private household consume and save a fraction of their income according to a Cobb-Douglas function. The government income not spent is saved, and the sum of public and private savings determines the regional disposable saving, which enters the Global Bank as in the core ICES.

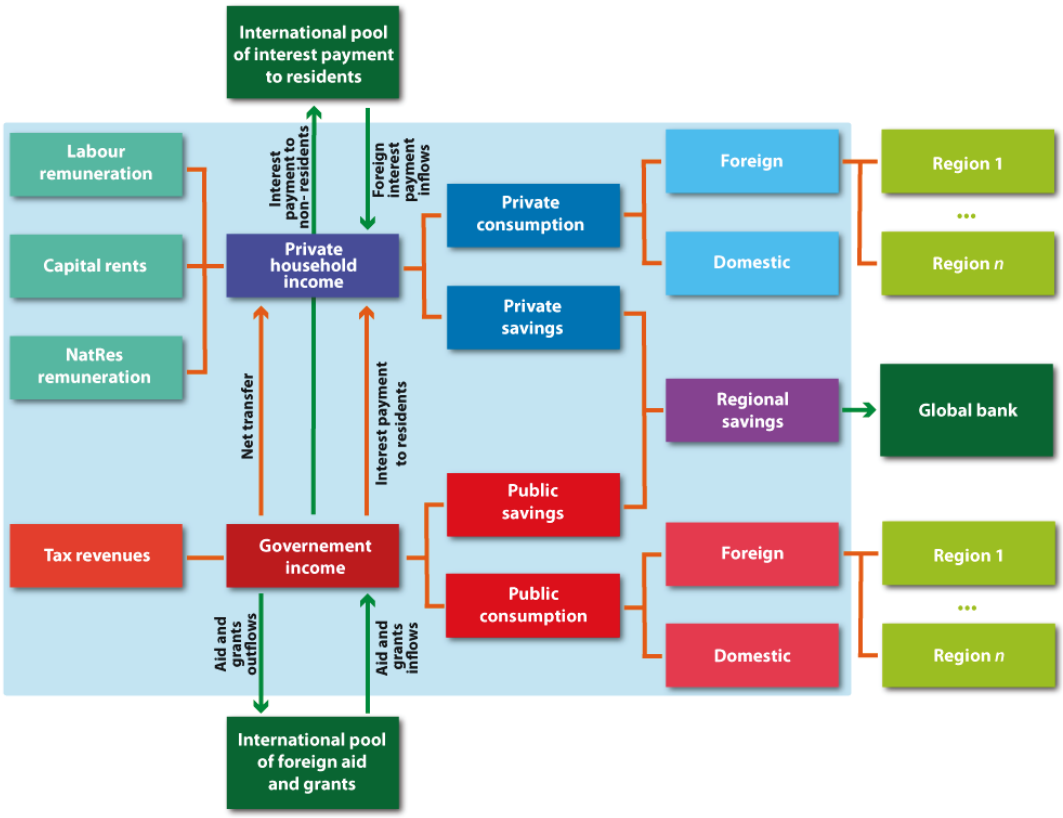


Figure A2 - Sources and uses of regional household income

The recursive-dynamic feature is described in Figure A3. Starting from the picture of the world economy in the benchmark year, by following socio-economic (e.g. population, primary factors stocks and productivity) as well as policy-driven changes occurring in the economic system, agents adjust their decisions in terms of input mix (firms), consumption basket (households) and savings. The model finds a new general (worldwide and economy-wide) equilibrium in each period, while all periods are interconnected by the accumulation process of physical capital stock, net of its depreciation. The matching between savings and investments only holds at the world level; a fictitious world bank collects savings from all regions and allocates investments following the rule of highest capital returns.

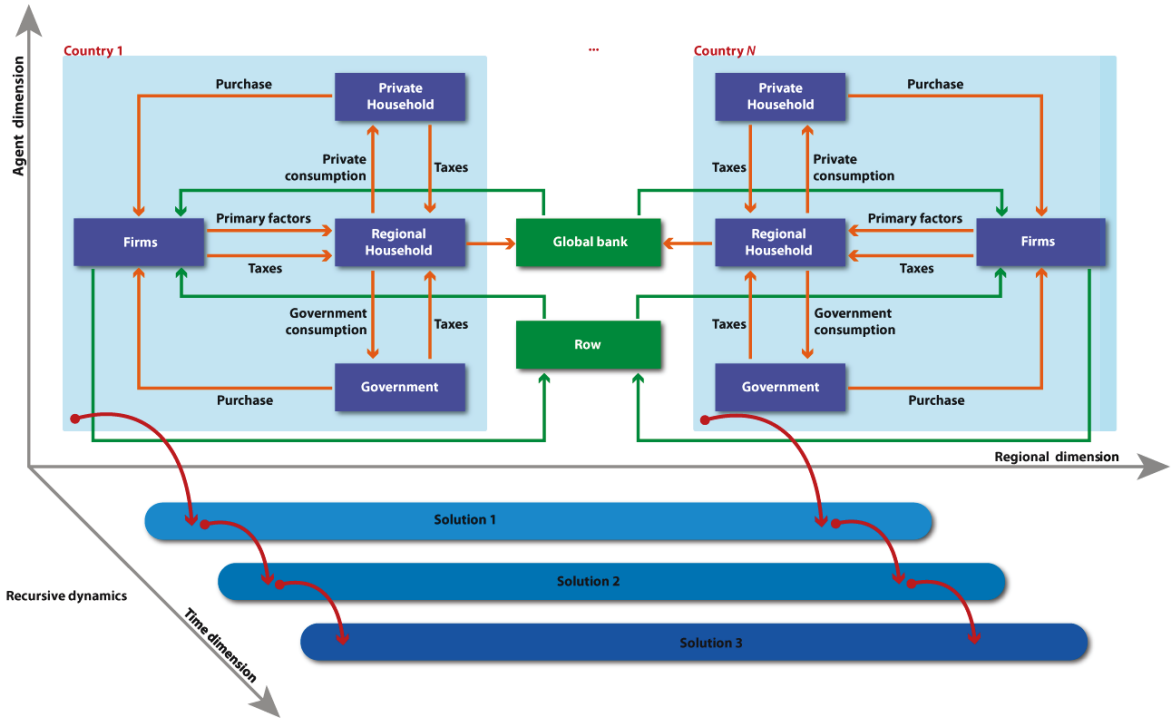


Figure A3 - Recursive-dynamic feature of ICES model

Regional and sectoral aggregation

ICES is a Computable model: all the model behavioural equations are connected to the GTAP 8 database (Narayanan et al., 2012), which collects national social accounting matrices from all over the world and provides a snapshot of all economic flows in the benchmark year. Being based on the GTAP database, ICES has worldwide coverage. In this analysis, we consider 45 countries/regions (Figure A4 and Table A 1).

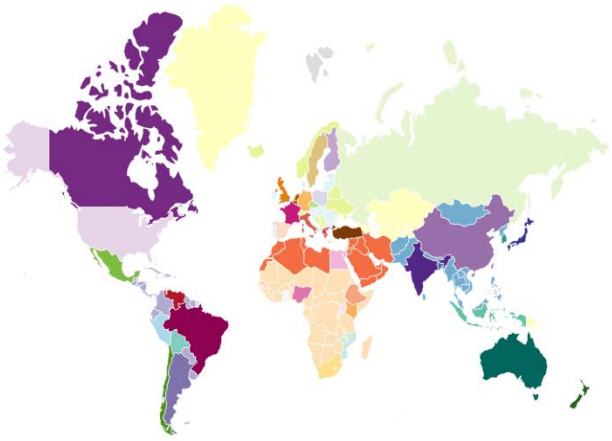


Figure A4 – Regional aggregation ICES model

Countries /macro-regions					
1	Australia	16	Chile	31	RoEU
2	NewZealand	17	Peru	32	RoEurope
3	Japan	18	Venezuela	33	Russia
4	SouthKorea	19	RoLACA	34	Turkey
5	Bangladesh	20	Benelux	35	Egypt
6	China	21	Czech_Rep	36	RoMENA
7	India	22	Finland	37	Ethiopia
8	Indonesia	23	France	38	Ghana
9	RoAsia	24	Germany	39	Kenya
10	Canada	25	Greece	40	Mozambique
11	USA	26	Italy	41	Nigeria
12	Mexico	27	Poland	42	Uganda
13	Argentina	28	Spain	43	SouthAfrica
14	Bolivia	29	Sweden	44	RoAfrica
15	Brazil	30	UK	45	RoW

Table A 1: ICES countries /macro-regions

Each socio-economic system is then divided into 22 sectors (Table A2).

Sectors			
1	Agriculture	12	Fossil Electricity
2	Livestock	13	Clean Electricity
3	Processed Food	14	Heavy Industries
4	Forestry	15	Light Industries
5	Fishing	16	Transport
6	Other Mining	17	Water
7	Coal	18	R&D
8	Oil	19	Market Services
9	Gas	20	Health
10	Oil Products	21	Education
11	Nuclear Fuel	22	Public Services

Table A2: ICES sectors

References

Burniaux J-M., Truong T.P. (2002), GTAP-E: An Energy-Environmental Version of the GTAP Model, GTAP Technical Paper n.16.

Delpiazzo, E., R. Parrado, G. Standardi, (2017), "Extending the Public Sector in the ICES Model with an Explicit Government Institution", FEEM Nota di Lavoro 11.2017

GTZ (2009) Energy-policy Framework Conditions for Electricity Markets and Renewable Energies. Eschborn, Germany

Hertel T.W. (Ed.) (1997), Global trade analysis: Modeling and applications, Cambridge and New York: Cambridge University Press.

Narayanan, G., Badri, Angel Aguiar and Robert McDougall, Eds (2012), Global Trade, Assistance, and Production: The GTAP 8 Data Base, Center for Global Trade Analysis, Purdue University

OECD/IEA (2005) Projected costs of generating electricity. IEA, Paris.

Ragwitz M et al. (2007) OPTRES: Assessment and optimisation of renewable support schemes in the European electricity market. Available at: http://www.optres.fhg.de/OPTRES_FINAL_REPORT.pdf

REN 21 Renewable energy Policy Network for the 21st Century. Available at: http://www.ren21.net/