# *Assessing costs and benefits of current climate negotiations*

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## Abstract

Last December 2015 the Parties under the UNFCCC succeeded in reaching the so-called Paris Agreement (COP21), which represents a timid step towards a burden sharing involving all countries in emission mitigation actions. However, given the heterogeneity of countries and their relative differences in vulnerability, compensating schemes for the most vulnerable countries are required to reach a successful agreement. This paper addresses the debate about the Green Climate Fund (GCF), the main compensating measure under a global climate regime, regarding the allocation mechanisms that are still under discussion. A dynamic climate-economy computable general equilibrium model (GDynE) is developed by considering both a monetary evaluation of climate change damage costs and two alternative criteria in the GCF resources allocation. Results show that, despite the high costs associated to the implementation of mitigation actions, developing countries would face even higher costs in case of inaction. Furthermore, the preference of a country for an allocation method is strongly influenced by its characteristics and needs. Consequently, our main policy advise is to design a well structured country-specific GCF in order to maximize country participation in a global agreement.

**Keywords:** Climate costs, Climate negotiations, Burden sharing, Mitigation costs, Green Climate Fund, GDynE, Clean energy technologies

**J.E.L. Codes:** C68; H23; O44; Q54

## 1. Introduction

The definition of a new climate regime is one of the most crucial challenges the world is currently facing. Indeed, incentives for free-riding along with the international norm of voluntary participation to international agreements appear to doom the realization of climate agreements (Nordhaus, 2015). Nevertheless, during the twenty-first Conference of the Parties (COP 21) held in Paris last December, the Parties under the United Nation Framework Convention on Climate Change (UNFCCC) succeeded in reaching the so called Paris Agreement. It will be effective in 2020, if ratified by at least 55 countries accounting in total for at least an estimated 55 percent of the total global greenhouse gas emissions (Art. 21). According to Article 2 of the Agreement, the main objective is to hold the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C. In order to achieve this long-term temperature goal, all Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, on the basis of their Nationally Determined Contribution (NDCs). It is worth noting that the new agreement is still based on one of the main and most controversial principles under the UNFCCC, namely the Common But Differentiated Responsibilities (CBDR) principle. Accordingly, peaking of emissions will take longer for developing country Parties, that can also benefit from financial and technical support provided by developed countries. The voluntary approach and the absence of sanctions make this agreement still weak. However, it represents a timid step forward towards a burden sharing involving all countries. In this regard, it is worth mentioning that even before the COP 21, some countries had already publicly outlined what post-2020 climate actions they intend to take. Among them, although the dispute about the interpretation of the CBDR principle (Brunnée and Streck, 2013), also some of the most vulnerable developing countries (e.g. SIDS, Kenya, Sierra Leone) voluntarily announced their commitment to implement national mitigation actions, according to their economic and technical capacity.[1] In spite of the insufficient contribution that these poor countries alone can give to mitigation, this reveals how the degree of vulnerability to climate change can contribute to explain the participation of Non-Annex I countries in mitigation actions. In view of this, to assess the vulnerability of a country to climate change is an important component of any attempt to define the magnitude of the threat (Kelly and Adger, 2000) as well as to reach a global agreement. According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability defines "the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change." In addition to IPCC reports, several attempts have been made to analyze the impacts of climate change, both in developed and developing countries (Kelly and Adger, 2000; Fussel and Klein, 2006; Fussel,

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[1] UNFCCC (2014), National Statement of Singapore Delivered by Dr Vivian Balakrishnan Minister for the Environment and Water resources at the UNFCCC COP-20 High Level Segment, 9 December 2014, Lima, Peru.
UNFCCC (2013), Statement by Prof. Judi Wakhungu, Cabinet Secretary, Ministry of Environment, Water and Natural Resources, Kenya at the High Level Segment of COP 19/CMP 9 in Warsaw, Poland, 21 November 2013.
UNFCCC (2013), Statement delivered by Hon Ibrahim Mansaray, Deputy Minister, Ministry of Transport and Aviation, and Head of the Sierra Leone delegation at the High Level Segment of the COP 19/CMP 9 in Warsaw, Poland, 21 November 2013.

2010) as well as their monetary evaluation (Anderson, 2006; Stern, 2007; EU, 2011; Arndt, 2015). The most recent study on this issue is the current establishment of a network of Mediterranean Experts on Climate and Environmental Change (MedECC) with the aim to provide a scientific assessment of climate change and its impacts in the Mediterranean Basin. The awareness of the impacts of climate change and of the physical, social and economic damages that it can cause, is essential to define action strategies both at national and international levels. In fact, it is possible to assume that the more the vulnerability of a country to climate change, the more the interest to act and to ask for active actions in current climate negotiations. Thus, as the poorest developing countries are also the most vulnerable to climate change, it is not surprising that they are those that advocate a more stringent climate regime.

Notwithstanding political issues and bargaining strategies, an active role of emerging economies and the other Non-Annex I countries in mitigation actions is essential, as it represents the only opportunity the world has to initiate the emission path that would limit the increase in temperature at 2°C. Moreover, aggressive early action is important, as it would allow to achieve more ambitious targets at lower costs (Bosetti et al., 2010). Thus, the main challenge for the forthcoming years is to persuade developing countries to mitigate. However, given the heterogeneity of countries and their relative differences in costs and benefits related to climate actions, there is need to set out compensating schemes for the most vulnerable countries in order to reach a successful agreement. So far, the main compensating measure under the current climate regime is the Green Climate Fund (GCF), discussed and approved during the COP 16 held in Cancun in 2010[2] and officially launched the following year at COP 17.[3] The purpose of the Fund 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, taking into account the needs of those developing countries particularly vulnerable to the adverse effects of climate change." It is worth noting that the focus of its activity is on both mitigation and adaptation. In fact, the criterion behind the allocation of resources aims for a 50:50 balance between adaptation and mitigation. Moreover, while all developing countries under the UNFCCC are eligible to receive

[2] Decision 1/CP.16
[3] Decision 3/CP.17

resources from the Fund, fifty per cent of the adaptation allocation is addressed to particularly vulnerable countries, namely least developed countries (LDCs), small island developing States (SIDS) and African States (Decision B.06/18). In February 2015, USD 10.2 billion was pledged to the Fund by developed countries and private sector both in the form of grants and loans (3.7%).[4] In May 2015, the signed contributions reached the 50% threshold (USD 5.5 billion)[5] required to start allocation so that these resources can now be used to finance activity-based projects in developing countries in the form of grants, concessional loans, equity or guarantees according to the degree of country vulnerability and the possible involvement of the private sector.[6] It is worth noting that these projects can be implemented only after the approval from the National Designated Authority (NDA). This is the interface between the country and the Fund and its main objective is to ensure that the projects are in line with national needs and priorities (GCF, 2015). Given the strong heterogeneity of developing countries, in fact, in order to maximize the likelihood of a successful climate agreement in the short term, it will be necessary to design the GCF according to countries' specific interests and weaknesses, becoming useful in reducing the distance between the domestic optimal solution desired by each country from the climate negotiations and the final global agreement achieved (Costantini et al., 2016). However, the debate about the GCF and its operational rules is still open, especially with regard to the resource allocation issue. According to developed countries, USA in particular, emerging economies should be excluded from the list of eligible countries, given their high contribution to global emissions. On the other hand, in the event of a climate regime with a burden sharing involving also emerging economies, they would incur so high mitigation commitments that they would need compensating measures to afford them and sign the new Agreement (Weikard and Dellink, 2014).

According to this negotiation framework, this paper addresses the debate about the GCF, especially regarding the resource allocation mechanisms that are still under discussion. A climate-economic computable general equilibrium (CGE) model is developed with the purpose of taking into account a monetary evaluation of climate change damage costs incurred by all countries as well as a mechanism describing the operationalization of the GCF. The purpose is twofold: i) to investigate costs and

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4 GCF/B.09/08

5 GCF (2015), Status of Pledges and Contributions made to the Green Climate Fund, Status Date: 21 May 2015.

6 GCF/B.09/08

benefits of ongoing climate negotiations, with particular emphasis on developing countries, and ii) to examine the role of the GCF as a compensating measure in fostering the realization of a more efficient climate agreement.

The rest of the paper is organized as follows. Section 2 presents a literature review concerning the GCF and the existing climate-economic models, thus bringing to Section 3 where the model used in the analysis is described. In Section 4 the empirical results are discussed while Section 5 provides some concluding remarks.

## 2. Literature review

In view of the need for a new climate regime, during last years the literature debate mainly focused on climate negotiations. Several studies have been conducted, especially about the role of developing countries (Kasa et al., 2008; Cosbey, 2009; Betzold et al. 2012; Costantini et al., 2016) and about equity as a principle for defining a fair burden sharing (Markandya, 2011; Garibaldi, 2014; Klinsky and Winkler, 2014; Morgan and Waskow, 2014). However, after its introduction, great emphasis has been also given to the Green Climate Fund, especially about how to finance the Fund and how to allocate its resources among developing countries (Jung, 2013; Noble, 2013; Polycarp et al., 2013; Vieweng, 2013). Although some decisions have been made on this point, investigating alternative criteria for the allocation is still a debated issue, as these choices significantly influence the outcome (Muller, 2014). With regard to the first point (i.e. how to finance the GCF), Silverstein (2011) argues that financing for the GCF could be generated from transferring a percentage of the collected revenues from a carbon tax. This percentage should differ among countries according to their historical responsibilities for GHG emissions and for their national wealth. Fenton et al. (2014), on the other hand, argue that long term debt owed by developing countries to developed ones could provide an alternative source for financing the GCF. According to this study, this would contribute to cover one third of the global sum requested by the Fund. So far, contributions to the GCF have been collected through voluntary country pledges but, as stressed by Cui et al. (2014), "establishing a clear method for allocating the finance responsibilities among Annex II countries may contribute to stabilizing the finance contributions". In his study, two main criteria are examined, namely an allocation method based on environmental responsibility and another based on economic capacity. Then, in order to obtain a method in line with the Common But Differentiated Responsibilities Principle (CBDR), the two criteria are aggregated through the population-based voting concept of preference score compromises (PSC), proposed by Müller (1999). The study conducted by Cui et al. (2014), also investigates the other issue debated in literature (i.e. how to allocate the GCF resources among developing countries). In their view, the criteria behind the allocation should be established according to the dual purpose of the Fund. Accordingly, for the adaptation purpose, a fair allocation should be guaranteed giving priority to the most vulnerable countries; for mitigation, on the other hand, the focus is on abatement efficiency, reached by financing those countries that commit themselves to mitigate. The study concludes that, following the GCF Board decision of a balance between adaptation and mitigation, the two approaches should be combined in order to reach both abatement efficiency and adaptation fairness of the GCF. Furthermore, according to Silverstein (2011), in order to fairly distribute funding across countries, allocation rules should be based on national needs of developing countries. In fact, given the profound heterogeneity of these countries, the allocation choice must be country-specific and, as stressed by Hasson et al. (2010), it should depend on geographic and economic characteristics of countries. Finally, while a "floor allocation" for adaptation is set for the most vulnerable countries, according to Muller (2013), every eligible country should receive something and adaptation resources should be allocated in proportion to funding needs: a country would be allocated resources in proportion to the number of its inhabitants that are exposed to climate change, weighted by the country's vulnerability.

With the introduction of the GCF as a compensatory measure, Parties aim to overcome the deadlock in negotiations by influencing the behavior of developing countries in terms of a more active commitment in mitigation actions. Consequently, climate-economic models focusing on developing countries are required to investigate this issue. Given the many interlinked dimensions of climate change (e.g. science, economics, politics), so far several attempts have been made to reduce this complexity through the development of Integrated Assessment Models (IAMs), which combine an economic module with a climatic one. IAMs can be classified in Hard-linked or Soft-linked models, according to the way economic variables interact with the climatic module. In Hard-linked models this interaction is represented as a single system by a closed loop, describing a cause and effect chain of climate change. As an example, the DICE (Dynamic Integrated Climate and Economy) model developed by Nordhaus and Yang (1996) and its regional version RICE (Regional Integrated Climate and Economy), belong to this category. They are used to calculate the optimal balance between greenhouse gas abatement and economic damages from climate change in order to maximize intertemporal welfare (Doll, 2009). In soft-linked models, such as the IMAGE (Integrated Model to Assess the Global Environment), climatic and economic modules run separately and they are connected exogenously in a causal chain through an output/input exchange process. Other models are the MERGE (Model for Evaluating Regional and Global Effects of greenhouse gases reduction policies), the PAGE (Policy Analysis of the Greenhouse Effect) and the FUND (Climate Framework for Uncertainty, Negotiation and Distribution). Moreover, the FEEM (Fondazione Eni Enrico Mattei) developed an Integrated Assessment Model called WITCH (World Induced Technical Change Hybrid model) designed to evaluate the impacts of climate policies on global and regional economic systems and to provide information on the optimal responses of these economies to climate change. Currently, three of these models (PAGE, FUND and DICE) are also the most commonly used to assess the economic impacts of climate change (Estrada et al., 2015). Indeed, these models provide a damage function, generally treated as a polynomial function of temperature change, for both market and non market sectors (PAGE, FUND) or for market sectors only (Ortiz and Markandya, 2009). Finally, CGE models have been used extensively for analyses of the impact of carbon taxes and other policy instruments in the economy and resulting emission reductions (Ortiz and Markandya, 2009). A CGE model is a multi-sector and multi-country model, representing agents and market interactions as well as international trade. In general, they are characterized by the absence of a climate module. However, as CGE models combine realistic data with a general equilibrium structure, they can be used in order to assess the economic impacts of climate change. Recently, climate-economic CGE models have also been applied to investigate mitigation and GCF issues (Cui et al., 2014, Markandya et al., 2015). In particular, Markandya et al. (2015) use the GTAP (Global Trade Analysis Project) model in order to investigate the trade-offs between economic growth and low carbon targets for both developing and developed countries. Their study is characterized by a specification of a Fund into the model. Starting from this, we develop a GTAP model in which both the cost of climate change and a compensatory measure are combined.

## 3. Model

The model used to carry out the research is the GDynE, an energy-environmental version of GDyn developed by Markandya et al. (2015), resulting from merging GDyn with GTAP-E.

GTAP-E is an energy-environmental version of the standard CGE GTAP static model (Burniaux and Truong, 2002; McDougall and Golub, 2007), developed to simulate mitigation policies. The standard version of GDyn (Lanchovichina and McDougall, 2000), on the other hand, is a recursive-dynamic extension of the standard GTAP (Hertel, 1997), designed for a better treatment of long-run simulations and enriched by new features: international capital mobility, adaptive expectations as well as the fact that time enters the model as an explicit variable and not as an index, allowing for an easy implementation of the dynamic aspects.

The GDynE developed by Markandya et al. (2015) uses the GTAP-Database 8.1, updated to 2007. It is characterized by a simulation of the GCF, through a mechanism for funding a global carbon fund, as a tool to enhance the capacity of developing countries to actively contribute to mitigation actions. In particular, the Fund is financed with a percentage of revenues gathered through a carbon tax and then distributed among developing countries according to a parameter based on their GDP. Starting from this model specification, the version of the model developed to carry out this research is enriched by an updated criterion to redistribute the Fund's resources and by the introduction of the cost of climate change into the model. This cost represents the monetary evaluation of damages caused by climate change. In other words, it represents a monetary evaluation of vulnerability and, consequently, it is one of the main aspects influencing countries' behavior in climate actions. Adding it into a CGE model can contribute to foster the results, allowing for a more complete representation of reality.

In terms of country and sector coverage, we consider 23 regions and 21 sectors. With regard to the former, following the Kyoto Protocol scheme, we differentiate between Annex I (Canada, European Union, Former Soviet Union, Japan, Korea, Norway, United States, and Rest of OECD) and non-Annex I countries (Brazil, China, India, Indonesia, Mexico, African Energy Exporters, American Energy Exporters, Asian Energy Exporters, Rest of Africa, Rest of America, Rest of Asia and Rest of Europe). It is worth noting that within the second group, we distinguish i) single countries (emerging economies with strong bargaining positions in the negotiations and eligible to emission cut commitments), ii) three groups (one per geographic area) of energy exporter countries and iii) all the remaining developing countries without an energy-based economy.

Considering the sectoral aggregation, we distinguish 21 industries: Food, beverages and tobacco; Textile; Wood; Pulp and paper; Chemical and petrochemical; Non-metallic Minerals; Basic metals 1; Basic metals 2; Machinery equipment; Transport equipment; Other manufacturing industries; Agriculture; Transport; Water; Air transport and Services, while energy commodities have been disaggregated in Coal, Oil, Gas, Oil products and Electricity. [7]

Finally, in terms of the temporal dimension (t), we consider a time horizon to 2050, shaping periods as a 5-year temporal structure.

### *3.1 The cost of climate change*

The need to determine the cost of climate change is one of the most debated issues, as it represents a measure of the phenomenon and, at the same time, it influences countries' negotiating positions and efforts in fighting climate change. As illustrated by Tol (2009), during the last decades several attempts in this field have been made by applying different methods such as the enumerative method that adds up the values of different impacts of climate change obtained from natural science papers (Fankhauser, 1995; Nordhaus and Boyer, 2000); the statistical approach, in which regressions are used to estimate the welfare impact or, finally, by shocking a CGE model through results from enumerative studies (Tol, 2015). Nevertheless, given the uncertainty of the future and of climate change, results are very different one from the other and the quantitative assessment is still uncertain and incomplete (Tol, 2015). However, while climate cost estimates are quite different one from the other, all these studies agree on a fact: climate change is affecting the world, and developing countries

[7] See Table A3- A6 in Appendix A for a detailed description of regional and sectoral aggregates

are suffering the highest costs. For this reason such an evaluation, although unsure, is crucial in order to try to assess and face the risks.

The first contribution with this regard is the study conducted by Fankhauser (1995), in which this cost is estimated to be USD 20 per ton of $CO_2$ emitted. During the following years, several estimations of the cost of climate change have been made. One of the first attempts is represented by the Mendelsohn model[8] that estimates the global impact to be very small (0.3% of global GDP). This optimistic result was mostly due to the fact that it considers only five market sectors, namely agriculture, water, forestry, energy and coastal zones. Thus, results are quite different when considering also non-market sectors, such as health and environment (Tol, 2002) or catastrophic climate impacts (Nordhaus and Boyer, 2000). In the latter case, for example, between 3° C and 6°C warming the Nordhaus model estimates a global cost from 2% to more than 10% of global GDP. In the light of the crucial role of these non-market factors, the Stern Review (2007) analyzes the physical impacts of climate change on economy, human life and environment, as well as the risk of catastrophe and an examination of the resource costs of different technologies and strategies to reduce GHGs. Through the use of an Integrated Assessment Model (IAM), the study concludes that "if we don'tact, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more" (Stern Review, 2007, p. vi). During last years, evaluations of the costs of climate change have been made also at region and country-level. Anderson (2006), for example, investigates the impact of climate change on Sub-Saharan Africa and South Asia and concludes that in 2100, with an increase of 3.9°C in global temperature, the loss of GDP would amount, respectively, in 1.9% and 2.5%. In 2011 the European Union, following the Stern Review, estimates the economic impacts of climate change, i.e. the costs of inaction for Europe. Different models have been used for sectoral evaluations, then linking results in a CGE model to look at the global economic costs of climate change in Europe. This is found to be equal to 4% of European GDP[9]. With regard to country-level studies, the most recent is the one conducted by Arndt et al. (2015) for Vietnam. By

[8] Mendelsohn et al. (1998)

[9] European Union (2011), Climate Cost: The Full Costs of Climate Change, Summary of Results from the Climate Cost project, funded by the European Community's Seventh Framework Programme

combining sectoral results in a CGE model, they find that climate change is likely to reduce national GDP by between 1% and 2% by 2050. Given the crucial role of this issue in the international climate debate, in November 2011, the Climate Vulnerable Forum[10] commissioned the independent organization DARA to assess the human and the economic costs of the climate crisis in view of the 18th Conference of Parties. Consequently, in 2012 the second Climate Vulnerability Monitor was released (DARA, 2012). It investigates both climate change and carbon economy impacts for 184 countries. With regard to climate costs, DARA follows the enumerative method using 22 indicators, representative of four areas: environmental disasters, habitat change, health impact and industry stress.[11] Costs associated to each indicator come from the results of scientific research and from the application of specific models. It is worth noting that DARA estimates also include non-market impacts and environmental disasters (e.g. losses from biodiversity, sea-level rise etc.), generally omitted by most of current studies. These elements, as stressed by Stern (2007), contribute to provide high estimates of the cost of climate change and explain most of the discrepancies among existing studies. The second point is particularly important, as stressed by IPCC (2012), according to which in most cases "loss estimates are lower bound estimates because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected in estimates of losses". The study concludes that in 2010 the global cost due to climate change was USD 609 billion (about 1% of world GDP) and in 2030 it is expected to be USD 4345 billion (about 2% of world GDP).[12] Finally, by incorporating the effect of temperature increase on GDP growth rate into the DICE model, Moore and Diaz (2015) find that the cost of climate change for poor countries is even much higher than what was suggested in other studies: they estimate a reduction of 40% of per-capita GDP by 2100.

Although aware of the uncertainties related to each of these estimates of climate damages, given the robust methodology used and the availability of updated information for a comprehensive number of

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[10]The Climate Vulnerable Forum (CVF) is an international cooperation group founded in 2009 by the Maldives, that now includes 20 countries that face significant insecurity due to climate change.

[11] See Table A1 in Appendix A

[12] For a detailed description of DARA methodology, see DARA (2012), Methodological Documentation For The Climate Vulnerability Monitor 2nd Edition

countries, the result deriving from DARA's study is the one used as the starting point to take into account the cost of climate change in the model.[13]

As illustrated in equation (1), the cost of climate change over time depends on $CO_2$ concentration in the atmosphere rather than on emissions flow.

$$STCO_t = STCO_{t-1} \cdot (1-d) + E_t \quad (1)$$

Where E is the emission flow and d indicates the decay rate of $CO_2$ in atmosphere, i.e. the speed at which carbon is removed from atmosphere. According to the Bern model, favored by the IPCC, there is not a unique decay rate d, but "the $CO_2$ concentration is approximated by a sum of exponentially decaying functions, one for each fraction of the additional concentrations, which should reflect the time scales of different sinks".[14] However, if we look at historical data provided by the National Oceanic and Atmospheric Administration (NOAA), the decay rate of $CO_2$ in atmosphere (d) can be estimated in about 13000 Mt of $CO_2$ per year, among 0.5% and 1% of $CO_2$ concentration. This percentage is low if compared to studies according to which it is possible to consider one decay rate and it can be up to 2.5% of concentration,[15] but it is in line with those that calculate the decay rate due to natural processes in about 3ppm per year.[16] Nevertheless, since concentration data also include emissions other than those coming from fossil fuels (e.g. emissions from land use) and not considered in the GTAP model, we cannot calculate the stock of $CO_2$ endogenously by applying (1). Accordingly, the atmospheric concentration enters the model as an exogenous variable. In particular, NOAA

[13] It is worth noting that the information about the cost of climate change provided by DARA is different from the one given by the World Bank Indicator "Adjusted savings: carbon dioxide damage". The latter, in fact, is estimated as the tons of carbon emitted by a country times USD 20 (Fankhauser 1995). Thus it depends on the level of emissions in each country and it indicates the cost of climate change caused by each country. On the contrary, DARA data give an evaluation of the costs caused by climate change sustained by countries. In other words, it is a cost due to their vulnerability rather than to their responsibilities. For this reason it has been selected to carry out the research.

[14] http://unfccc.int/resource/brazil/carbon.html

[15] http://euanmearns.com/the-half-life-of-co2-in-earths-atmosphere-part-1/

[16] http://www.hydrogen.co.uk/h2_now/journal/articles/2_global_warming.htm

historical data inform the model until 2010,[17] then further projections are taken from IPCC, as a simple mean between results obtained from different models applied to the IPCC A1 Scenario.[18]

Once obtained the concentration data, the first step is to define the average cost function. The average cost (CCM) is the ratio between the total cost of climate change (CCT) and the stock of $CO_2$ in the atmosphere.

$$CCM_{t0} = \frac{CCT_{t0}}{STCO_{t0}} \qquad (2)$$

As a result, starting from DARA data, the average cost of climate change in 2007 is USD 132 per Gt of $CO_2$ and the cost of climate change over time is calculated according to the formula described in equation 3.

$$CCM_t = CCM_{t-1} + (STCO_t - STCO_{t-1})^{\alpha} \qquad (3)$$

The parameter α has been calibrated as equal to 0.95 so that, by applying this formula, the global total cost of climate change obtained (4) is coherent with a 4% loss of global GDP.

$$CCT_t = CCM_t \cdot STCO_t \qquad (4)$$

The choice of a 4% loss is not arbitrary but has been chosen starting from the level of projected concentration in 2050 (about 630 ppm). This high concentration is associated to a temperature increase of more than 3°C, in a range from 2.4°C to 5.5°C (IPCC, 2007).[19] By looking at several recent studies investigating the cost of climate change associated to a temperature increase higher than 2.5°C (IPCC, 2007; Stern 2007; Dellink et al., 2014; Tol, 2015[20]), we found an average loss of 4% of global GDP.[21]

Since the purpose is to investigate the impact of climate damages over countries, the global cost of climate change, once obtained, must be distributed among the 23 regions of the model (∀r∈(1,N),with

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[17] NOAA estimates the concentration of CO2 in the atmosphere at 393.07 ppm in 2007 and at 401.09 in 2010.
[18] IPCC (2007)
[19] See Table A2 in Appendix A
[20] Among the studies included in the review made by Tol (2015), we consider Nordhaus (2008), Maddison and Rehdanz (2011), Roson and van der Mensbrug (2012) and Nordhaus (2013).
[21] Given the uncertainties about the cost of climate change and the controversial opinions on this issue in literature, a further analysis would be testing other trends of the function. However, although differences in the magnitude of damages, this would not change the relative position of countries.

N=23). The criterion used for this purpose is to subdivide the cost in accordance with the vulnerability of the region to climate change: the higher the vulnerability, the higher the share of cost the region must face. The vulnerability measure used for this purpose is represented by the ratio between the Vulnerability Index (VULN) and the Readiness Index (READ) developed by the University of Notre Dame for the calculation of the Notre Dame Global Adaptation Index (ND-GAIN).[22] It aims to identify the vulnerability degree of a region on its readiness to deal with climate change. One of the advantages of the ND-GAIN Indices is that, while considering vulnerability and readiness in a combination of dimensions, they provide reliable information in a single measure that is available for a comprehensive number of countries.[23]Thus, the cost of climate change for each region ($CCR_r$) depends on its vulnerability weighted for the share of global population represented:

$$CCR_r = CCT_w \cdot \left[ \left( \frac{POP_r}{POP_w} \cdot \frac{VULN_r}{READ_r} \right) \Big/ \sum_{r=1}^{N} \left( \frac{POP_r}{POP_w} \cdot \frac{VULN_r}{READ_r} \right) \right] \tag{5}$$

Where $POP_r$ and $POP_w$ are, respectively, the regional and global population.[24]

The regional damage represents the value associated to the negative externality caused by climate change. Given the complexity of mechanisms linking climate damages to both market and non-market aspects, we choose to compute climate costs as directly reducing wealth, without disentangling specific impacts on different aspects of utility function.

Thus it can be included in national accounts, following the approach of the Green GDP. This is a methodology developed to find a measure of sustainability. As stated in the Brundtland Report (1987),

[22] University of Notre Dame (2013)

[23] The Vulnerability Index measures a country's exposure, sensitivity and adaptive capacity (components) to the negative effects of climate change. It considers six life-supporting sectors: food, water, health, ecosystem service, human habitat, and infrastructure. 36 indicators (two per component in each sector) contribute to the measure of vulnerability, obtained as a simple mean of the sector scores, which are the average scores of component indicators. Readiness measures the ability of a country's private and public sectors to absorb investment resources and successfully apply them to reduce climate change vulnerability. Readiness includes indicators for three components (social, economic and governance indicators) not weighted equally (Economic Readiness is 50% of the readiness score while governance and social readiness are 25%).

[24] The ratio between the vulnerability and readiness indices has been normalized (min = 0; max = 2) and then it is kept constant over time, as there is not information about future projections, especially because of uncertainties with regard to readiness issues. Thus, the variation in the regional distribution of damage cost is due to variations in population dynamics data. Obviously, these data do not take into account deaths caused by climate change and, as a consequence, actual population could be lower than the one considered. Nevertheless, the only way to take it into account is to add this information exogenously.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[25] During the last years, several attempts have been made to measure sustainability in terms of capacity of the economy to maintain or to increase the level of welfare over the years. Besides the construction of indices such as the Environmental Sustainable Index (ESI), the main attempts start from Standard National Account (SNA) and aim to modify the GDP by taking into account environmental issues, obtaining a Green GDP. Most of these contributions are based on Weitzman (1976), according to which a correctly adjusted Net National Product (NNP) can serve as an indicator of welfare and can measure what can be consumed today without reducing future consumption possibilities. This is the hicksian view of income, that defines income as what can be consumed this year without being poorer at the end of the year (Stiglitz, Sen and Fitoussi, 2009). In other words, the NNP represents the maximum consumption level that can be sustained. Several attempts have thus been made to modify NNP in order to obtain a sustainability measure by taking into account also environmental issues; for example, by adding in the computation environmental services and deducting environmental costs (Hamilton, 1996). The green GDP charges GDP for the depletion of damage to environmental resources without giving an assessment of how far we are from these sustainable targets (Stiglitz, Sen, Fitoussi, 2009). For this reason it has been improved by Hamilton and Clemens (1999) through the computation of the so called Genuine Savings (G). Starting from national accounts, it consists in adjusting net savings by deducting depletion of natural resources and of environmental damages and by adding investments in human capital. Positive values of G mean presence of sustainability, while negative values of G describe a situation in which the country is not on a sustainable path.

Accordingly, in order to represent the wealth reduction caused by the cost of climate change on the economy, it is included in national accounts by deducting the regional cost of climate change from income.

$$INCOME = PRIVEXP + GOVEXP + SAVE - CCR \tag{6}$$ [26]

[25]Brundtland Commission (1987), Report of the World Commission on Environment and Development, United Nations.

[26] Where PRIVEXP is private consumption expenditure, GOVEXP is government expenditure, SAVE is net savings and CCR is the regional cost of climate change.

Basically, by applying (6), the impact of climate damage on welfare is represented and can be seen in the computation of equivalent variation (EV). It is worth noting that, although climate damages impact the economy, they are not perceived immediately. Consequently, since the internalization of the externality into the model through the climate damage component does not provide enough incentive to moderate pollution considerably (Bosetti, Massetti and Tavoni, 2007), emissions can enter the model exogenously.

### *3.3 Simulation details*

The model is used to investigate the role of climate change damages and GCF in influencing the behavior of countries in climate negotiations. As already mentioned, it considers 23 regions, 21 sectors and a time horizon to 2050.

The projections for macro variables such as population, GDP and labour force, are given by the combination of several international sources. GDP projections are taken from the comparison of four sources: the OECD Long Run Economic Outlook, the GTAP Macro projections, the IIASA projections used for the OECD EnvLink model, and the CEPII macroeconomic projections used in the GINFORS model. Population projections are taken from the UN Statistics (UNDESA), while projections for the labour force (skilled and unskilled) are taken by comparing labour force projections provided by ILO (which result as aggregate) with those provided by the GTAP Macro projections (where skilled and unskilled labour force are disentangled).

The baseline scenario corresponds to a Business as Usual Scenario (BAU) built upon the Current scenario of $CO_2$ projections provided by the International Energy Agency (IEA) in the World Energy Outlook (WEO) 2013 (IEA, 2013b). It embodies the effects of only those government policies and measures that had been adopted by mid-2013 (OECD/IEA, 2013). It is worth noting that to build the baseline, we projected the global economy from 2007 to 2015, with $CO_2$ emissions being exogenous to replicate the current distribution among regions.

The policy option available for reaching abatement is a global emission trading scheme (ETS) in which all countries participate in mitigation and the burden sharing is always the same; it corresponds to the one given by WEO 2013, which is based on the technological capabilities of countries. This policy option is associated to two mitigation targets: i) the 450 ppm Scenario developed by IEA, namely an emission path that limits the global increase in temperature to 2°C, and thus limits the GHG concentration in atmosphere at 450 ppm (parts per million); ii) the 550 ppm Scenario, which represents a less stringent target that aims to limit GHG concentration at 550 ppm.

Finally, following last negotiations agreements, we build two more scenarios in accordance with the 450 ppm target. They aim to investigate two different criteria for the allocation of GCF resources:

i) GCF-neg - This scenario is in line with ongoing negotiations: GCF resource allocation is balanced between adaptation and mitigation projects, with fifty per cent of the adaptation allocation addressed to particularly vulnerable countries.

ii) GCF-alt – Total resources are allocated among countries by combining their adaptation and mitigation needs. Once resources are received, they are balanced between adaptation and mitigation projects.

To sum up, five scenarios are investigated:

1. Business As Usual (BAU)
2. Emission Trading with 450 ppm target (GET-450)
3. Emission Trading with 550 ppm target (GET-550)
4. Emission Trading with 450 ppm target and current GCF (GCF-neg)
5. Emission Trading with 450 ppm target and alternative GCF (GCF-alt)

### *3.4 The modeling specification of the GCF*

The main aspects of the GCF that must be modeled are i) how the GCF is funded and ii) how resources are distributed among developing regions.

As for the former, the state of the art is reproduced by initiating the GCF in 2015 with an amount of resources equals to 5.5 billion USD; from 2020 on, we suppose a shift from the current voluntary pledges to a compulsory measure in line with the modeling specification developed by Markandya et al. (2015) in which a certain percentage (α) of the revenues resulting from a carbon tax revenue (CTR) is devolved to finance the Fund as follows:

$$CTR(r) = \alpha(r) \cdot CTR(r) \tag{7}$$

In line with the ongoing negotiations, countries that must contribute to finance the GCF are the developed ones, with a percentage of carbon tax revenue α here supposed to be equal to 10%.

With regard to the second point, while in Markandya et al. (2015) resources were distributed among countries according to their GDP, here two alternative criteria, which correspond to the two GCF Policy Scenarios (GCF-neg and GCF-alt), are tested.

In the GCF-neg Scenario, we model the GCF reproducing its actual rules. Accordingly, 50% of the resources are allocated for mitigation and 50% for adaptation. With regard to mitigation resources, these are allocated among developing countries (∀m∈(1,M),with M=14)[27] according to their GDP share of the developing world's total (*gdp*). In fact, given that GDP and emissions are correlated, the more the level of GDP of a region, the more its mitigation potential.

$$gdp = \frac{GDP_m}{\sum GDP_m} \tag{8}$$

Allocation for adaptation, on the other hand, depends on the vulnerability to climate change of the region. As a consequence, to model the distribution of adaptation resources, we use the variable VULN previously described, adjusted to represent the vulnerability of a region relative to the total vulnerability of developing countries.

[27] The fourteen regions composed by developing countries are BRA, CHN, IND, IDN, MEX, EExAf, EExAm, EExAs, RAF, RAF2, RAM, RAS, RAS2, VNM.

$$vuln = \frac{VULN_m}{\sum VULN_m} \quad (9)$$

Furthermore, as GCF rules currently ask for the allocation of 50% of adaptation resources to LDCs, we adjust *vuln* so that the sum of values associated to LDCs equals 0.5, as described in equation (10), where $S$ is the subgroup of $M$ representing regions composed by LDCs (∀s∈(1,S),with S=6): [28]

$$vuln_W = 0.5 \cdot \frac{vuln_S}{\sum vuln_S} \quad (10)$$

As already mentioned, through this modeling specification, this scenario reproduces the current policy decisions made in the ongoing negotiations.

The GCF-alt scenario, on the other hand, investigates an alternative criterion to redistribute GCF resources. Contrary to the GCF-neg, in which resources are firstly balanced between adaptation and mitigation and subsequently allocated, in GCF-alt the total amount of resources is allocated among countries according to both their adaptation and mitigation needs through a combination of the GDP and vulnerability criteria previously described.

$$shf = \frac{gdp + vuln}{2} \quad (11)$$

Once resources are received by countries, their internal allocation is balanced between mitigation and adaptation projects.

## 4. Results

### *4.1 The impact of climate change*

Firstly, let us look at the first set of simulations, introducing the cost of climate change without the GCF mechanism. Accordingly, Tables 1 and 2 show, the impact of climate change in terms of GDP loss in BAU and in GET-450 Scenarios, respectively.

[28] Least Developed Countries are here represented by six regions, namely RAF, RAF 2, RAM, RAS, RAS2 and VNM.

As for the Baseline Scenario, developed countries are those which suffer the least from climate change, followed by China and the remaining emerging economies but India, that registers a higher loss due to its high vulnerability. On the other hand, it is not surprising that DCs are those who suffer the most, with a GDP loss higher than 16% in 2050. Furthermore, if we look at more disaggregated data, among DCs, the costs associated to African countries are even higher, reaching about a 38% loss.[29]

**Table 1 – Climate change impact on GDP per region in BAU (%)**

| GDP Loss (%) | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 0.23 | 0.27 | 0.32 | 0.38 | 0.46 | 0.55 | 0.67 |
| **CHN** | 2.15 | 1.94 | 1.78 | 1.74 | 1.74 | 1.85 | 2.01 |
| **IND** | 9.23 | 8.94 | 8.53 | 8.42 | 8.34 | 8.60 | 9.01 |
| **Other emerging** | 1.70 | 1.88 | 2.06 | 2.34 | 2.63 | 3.03 | 3.49 |
| **DCs-Eex** | 3.76 | 4.27 | 4.78 | 5.48 | 6.23 | 7.23 | 8.31 |
| **DCs** | 9.39 | 10.35 | 11.14 | 12.24 | 13.30 | 14.78 | 16.36 |
| **World** | 1.70 | 1.96 | 2.21 | 2.57 | 2.94 | 3.47 | 4.08 |

These results are in line with the existing literature, in confirming that although the quantitative assessment is still uncertain and incomplete, climate change is affecting the world and developing countries are suffering the highest costs (Tol, 2015). Several reasons can explain the higher economic costs of climate change for developing countries. Firstly, their geographic position: most low-income countries are located in low-mid latitudes, characterized by higher temperature increases. Secondly, developing countries are highly reliant on climate-dependent sectors, such as agriculture. Finally, they are less able to adapt because of the lack of institutions and financial resources (Tol, 2009).

After the introduction of the ETS (Table 2), climate damages decrease, both at world level (from 4% to 1% in 2050) and at regional level. In particular, DCs see a sharp reduction moving from a 16% GDP loss to 4%.

This Policy Scenario, in fact, is coherent with a mitigation path that reduces emissions in order to limit the atmospheric concentration at 450 ppm in 2050. This directly influences the cost of climate change. Indeed, lower emission flows due to mitigation actions reduce the stock of CO2 in atmosphere

[29] See Table B2 in Appendix B

and, consequently, the cost of climate change decreases over time. Nevertheless, this is a slow process, so that immediate high mitigation costs might prevent countries from taking actions. Thus, in order to investigate whether a country would benefit from participating in mitigation policies, Table 3 shows a comparison between the costs faced in the Policy Scenario (mitigation costs plus climate costs associated to this Scenario) with those faced in BAU (namely the costs of climate change). The difference between them reveals whether the country would benefit from actively participating in mitigation policies (positive values) or not (negative values).

**Table 2 – Climate change impact on GDP per region in GET-450 (%)**

| GDP Loss (%) | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 0.23 | 0.24 | 0.23 | 0.21 | 0.20 | 0.19 | 0.18 |
| **CHN** | 2.13 | 1.78 | 1.37 | 1.07 | 0.85 | 0.69 | 0.58 |
| **IND** | 9.12 | 8.04 | 6.29 | 4.83 | 3.74 | 2.93 | 2.36 |
| **Other emerging** | 1.67 | 1.66 | 1.47 | 1.29 | 1.13 | 1.01 | 0.92 |
| **DCs-Eex** | 3.71 | 3.87 | 3.63 | 3.41 | 3.26 | 3.10 | 2.93 |
| **DCs** | 9.25 | 9.22 | 8.12 | 6.99 | 6.02 | 5.17 | 4.48 |
| **World** | 1.68 | 1.75 | 1.63 | 1.48 | 1.35 | 1.22 | 1.12 |

All regions, apart from developed countries, would benefit from participating in abatement actions. The costs associated to climate change in the absence of mitigation, in fact, are much higher than those associated to the GET-450 Scenario. Thus, if a costs-benefits criterion were the only factor driving the active participation of developing countries, they would join the agreement. However, from a closer perspective this situation turns out to be more nuanced. To start with, despite being lower, the costs associated to the Policy Scenario are still too high to be faced in the immediate future by many developing countries. It is also worth noting that, while it is important to take early actions to cope with climate change (Bosetti et al., 2010), its effects may appear only in the long run, thus reducing the current incentive to mitigate. This is true, for example, in the case of China, whose benefits from participating in mitigation are clear only from 2035 on, while, in the short run, abatement costs still exceed climate damages. Also political issues arise: in line with the CBDR debate, developing countries demand developed economies to take the lead in mitigation policies, as global warming is the result of their industrial development. Consequently, participation is not an obvious choice, especially with such a challenging global target.

**Table 3 – Net benefits. GET-450 vs BAU**

| | | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **Developed** | Mitigation cost | -8,730 | -45,549 | -142,979 | -304,892 | -489,109 | -716,590 | -890,273 |
| | CCR 450 | -119,732 | -139,424 | -143,084 | -142,524 | -140,779 | -138,210 | -136,124 |
| | CCR BAU | -121,637 | -156,650 | -197,073 | -253,224 | -320,565 | -414,231 | -532,176 |
| | GET-450 vs BAU | -6,825 | -28,323 | -88,991 | -194,192 | -309,323 | -440,568 | -494,220 |
| **China** | Mitigation cost | -5,966 | -48,595 | -118,782 | -191,628 | -264,138 | -290,568 | -318,141 |
| | CCR 450 | -229,434 | -266,736 | -272,334 | -268,946 | -262,255 | -252,850 | -243,411 |
| | CCR BAU | -233,084 | -299,692 | -375,090 | -477,840 | -597,175 | -757,822 | -951,618 |
| | GET-450 vs BAU | -2,316 | -15,639 | -16,025 | 17,265 | 70,782 | 214,404 | 390,066 |
| **India** | Mitigation cost | -3,294 | -4,343 | -7,406 | -10,980 | -18,820 | -36,785 | -66,546 |
| | CCR 450 | -292,660 | -356,438 | -381,237 | -394,516 | -402,988 | -406,591 | -408,822 |
| | CCR BAU | -297,316 | -400,476 | -525,085 | -700,941 | -917,637 | -1,218,602 | -1,598,291 |
| | GET-450 vs BAU | 1,362 | 39,695 | 136,442 | 295,444 | 495,829 | 775,226 | 1,122,923 |
| **Other emerging** | Mitigation cost | -556 | -2,523 | -8,051 | -25,128 | -53,365 | -85,133 | -119,506 |
| | CCR 450 | -84,073 | -100,679 | -105,942 | -107,847 | -108,340 | -107,512 | -106,409 |
| | CCR BAU | -85,411 | -113,118 | -145,916 | -191,613 | -246,700 | -322,227 | -416,008 |
| | GET-450 vs BAU | 170,040 | 9,916 | 31,923 | 58,638 | 84,994 | 129,582 | 190,093 |
| **DCs-Eex** | Mitigation cost | -673 | -12,853 | -52,124 | -126,706 | -233,803 | -318,263 | -391,391 |
| | CCR 450 | -194,099 | -242,041 | -265,343 | -281,752 | -295,776 | -307,330 | -318,782 |
| | CCR BAU | -197,187 | -271,946 | -365,462 | -500,591 | -673,507 | -921,106 | -1,246,280 |
| | GET-450 vs BAU | 2,415 | 17,051 | 47,995 | 92,134 | 143,928 | 295,512 | 536,106 |
| **DCs** | Mitigation cost | -1,032 | -3,574 | -18,620 | -55,831 | -89,154 | -126,514 | -172,150 |
| | CCR 450 | -458,233 | -572,470 | -629,067 | -669,168 | -703,453 | -731,834 | -760,163 |
| | CCR BAU | -465,523 | -643,198 | -866,427 | -1,188,917 | -1,601,820 | -2,193,395 | -2,971,860 |
| | GET-450 vs BAU | 6,258 | 67,154 | 218,739 | 463,918 | 809,213 | 1,335,048 | 2,039,547 |

In order to investigate whether things may change for a less ambitious target, we introduce an intermediate scenario with less stringent abatement commitments, namely a 550 ppm target. Accordingly, Table 4 shows what would happen by applying the same costs-benefits criterion to the GET-550 Scenario.

In this case all countries would benefit from joining the Agreement, developed countries included, for they would see a reduction in their mitigation costs. As for developing countries, whilst they would see a reduction in their benefits due to higher climate costs, they would still take advantage from the Agreement. This is true especially for DCs, in line with their request for a stringent Agreement.

Things may change if we move from partial to general equilibrium considerations. In addition to the net-benefits criterion, the preference of countries over the two Scenarios can be investigated also through a measure of general welfare, here obtained as a change in equivalent variation (EV) compared to BAU. Accordingly, Table 5 shows a comparison between the two criteria for both GET-450 and GET-550 Scenarios. Since countries are asked to make a decision now for the future, in Table 5 all information have been discounted, on the base of a discount rate equal to 4%. This is an intermediate value, compared to the high (6%) and low (2%) discount rates resulting, respectively, from the ethical and descriptive approach.[30]

**Table 4 – Net Benefits. GET-550 vs BAU**

| | | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| Developed | Mitigation cost | -2,523 | -7,156 | -13,854 | -21,214 | -27,167 | -42,162 | -47,371 |
| | CCR 550 | -120,684 | -148,009 | -169,767 | -196,299 | -226,284 | -266,078 | -314,494 |
| | CCR BAU | -121,637 | -156,650 | -197,073 | -253,224 | -320,565 | -414,231 | -532,176 |
| | GET-550 vs BAU | -1,570 | 1,485 | 13,451 | 35,711 | 67,115 | 105,990 | 170,311 |
| China | Mitigation cost | -948 | -4,571 | -10,811 | -18,702 | -28,670 | -28,663 | -22,015 |
| | CCR 550 | -231,258 | -283,159 | -323,120 | -370,421 | -421,539 | -486,781 | -562,366 |
| | CCR BAU | -233,084 | -299,692 | -375,090 | -477,840 | -597,175 | -757,822 | -951,618 |
| | GET-550 vs BAU | 877 | 11,961 | 41,159 | 88,717 | 146,965 | 242,378 | 367,237 |
| India | Mitigation cost | -700 | -832 | -1,192 | -159 | -768 | -942 | -1,183 |
| | CCR 550 | -294,988 | -378,384 | -452,332 | -543,369 | -647,750 | -782,760 | -944,523 |
| | CCR BAU | -297,316 | -400,476 | -525,085 | -700,941 | -917,637 | -1,218,602 | -1,598,291 |
| | GET-550 vs BAU | 1,629 | 21,260 | 71,562 | 157,413 | 269,119 | 434,900 | 652,585 |
| Other emerging | Mitigation cost | -142 | -541 | -1,095 | -1,067 | -1,575 | -1,663 | -3,639 |
| | CCR 550 | -84,742 | -106,878 | -125,699 | -148,538 | -174,143 | -206,980 | -245,843 |
| | CCR BAU | -85,411 | -113,118 | -145,916 | -191,613 | -246,700 | -322,227 | -416,008 |
| | GET-550 vs BAU | 527 | 5,699 | 19,123 | 42,007 | 70,982 | 113,583 | 166,526 |
| DCs-Eex | Mitigation cost | -636 | -512 | -3,736 | -6,127 | -8,900 | -7,179 | -3,589 |
| | CCR 550 | -195,643 | -256,944 | -314,826 | -388,058 | -475,421 | -591,665 | -736,499 |
| | CCR BAU | -197,187 | -271,946 | -365,462 | -500,591 | -673,507 | -921,106 | -1,246,280 |
| | GET-550 vs BAU | 909 | 14,490 | 46,901 | 106,406 | 189,186 | 322,261 | 506,192 |
| DCs | Mitigation cost | -754 | -629 | -1,459 | -3,665 | -4,453 | -3,322 | -5,330 |
| | CCR 550 | -461,877 | -607,717 | -746,379 | -921,647 | -1,130,707 | -1,408,911 | -1,756,244 |
| | CCR BAU | -465,523 | -643,198 | -866,427 | -1,188,917 | -1,601,820 | -2,193,395 | -2,971,860 |
| | GET-550 vs BAU | 2,892 | 34,852 | 118,589 | 263,604 | 466,661 | 781,162 | 1,210,285 |

The first and most evident result is that, at the world level, the preference between the Scenarios strongly depends on the criterion used. From a partial perspective, that is by looking at discounted net benefits, the more ambitious GET-450 Scenario seems to be the world best solution, for it provides the highest benefits. This is due to the fact that the advantages coming from a reduction in climate change costs are much higher than the grater mitigation costs associated to this target. On the other hand,

[30] The ethical, or prescriptive, approach is based on what rates of discount should be applied; the descriptive approach is based on what rates of discount people (savers as well as investors) actually apply in their day-to-day decisions. (SAR, IPCC, 1996a, Chapter 4).

from a general perspective, welfare improvements are registered for the GET-550 Scenario.[31] At country level, the same conflict can be seen for the group of other emerging countries, while DCs and India, given their high vulnerability, always prefer the GET-450. As for those countries favoring the GET-550 Scenario, the positive effects on welfare can be seen by looking at the effects on the whole economy. Accordingly, Table 6 and Table 7 show the impacts of active mitigation commitments on GDP, in GET-450 and GET-550 Scenarios respectively.

**Table 5 – Policy vs BAU. Comparison between GET450 and GET-550 (Discount rate: 4%)**

| | GET-450 vs BAU | | GET-550 vs BAU | |
|---|---|---|---|---|
| | **Net discounted benefits** | **Total EV (discounted)** | **Net discounted benefits** | **Total EV (discounted)** |
| **Developed** | -539,895 | -1,697,529 | 124,494 | -58,783 |
| **China** | 178,017 | -924,687 | 295,067 | 37,080 |
| **India** | 948,111 | 1,249,841 | 527,692 | 543,656 |
| **Other emerging** | 171,836 | 57,169 | 137,920 | 130,896 |
| **DCs-Eex** | 363,161 | -303,414 | 383,743 | 253,857 |
| **DCs** | 1,615,717 | 1,236,702 | 934,680 | 919,820 |
| **World** | 2,737,131 | -381,918 | 2,403,741 | 1,826,526 |

**Table 6 – GET-450 vs BAU. GDP change**

| GDP change (%) | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 0.04 | 0.23 | 0.43 | 0.40 | 0.04 | -0.71 | -1.72 |
| **CHN** | -0.93 | -2.97 | -5.58 | -7.88 | -9.31 | -9.78 | -9.86 |
| **IND** | -0.34 | -0.11 | 0.80 | 1.92 | 2.85 | 3.91 | 4.81 |
| **Other emerging** | 0.19 | 0.94 | 2.17 | 3.32 | 3.47 | 2.22 | -0.69 |
| **DCs-Eex** | -0.30 | -1.18 | -3.37 | -7.59 | -13.30 | -18.71 | -23.21 |
| **DCs** | 0.18 | 1.23 | 2.95 | 4.42 | 5.18 | 6.10 | 6.82 |
| **World** | -0.11 | -0.28 | -0.68 | -1.38 | -2.31 | -3.19 | -4.07 |

**Table 7 – GET-550 vs BAU. GDP change**

| GDP change (%) | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 0.02 | 0.14 | 0.30 | 0.42 | 0.45 | 0.40 | 0.35 |
| **CHN** | -0.38 | -1.02 | -1.59 | -1.90 | -1.95 | -1.76 | -1.47 |
| **IND** | -0.16 | -0.07 | 0.40 | 1.09 | 1.80 | 2.67 | 3.54 |
| **Other emerging** | 0.10 | 0.45 | 1.01 | 1.59 | 1.98 | 2.17 | 2.16 |
| **DCs-Eex** | -0.10 | -0.21 | -0.24 | -0.21 | -0.15 | 0.15 | 0.63 |
| **DCs** | 0.10 | 0.72 | 1.86 | 3.25 | 4.59 | 6.26 | 8.06 |
| **World** | -0.04 | -0.03 | 0.05 | 0.18 | 0.34 | 0.59 | 0.95 |

[31] The same conclusions have been obtained by applying the same comparison for the lower discount rate (2%) and the upper one (6%). See Tables B4 and B5 in Appendix B.

Not surprisingly, all countries would benefit, in terms of GDP change, from implementing less stringent mitigation policies. Indeed, the greatest advantages are associated to those countries whose welfare would improve in the GET-550 Scenario, namely developed countries, China, other emerging countries and energy exporters. In fact, they would face huge economic damages in the GET-450 Scenario. Energy exporters, in particular, would lose about 23% of GDP (Table 6), as a consequence of the decrease in the international demand for fossil fuels due to mitigation actions.

Within such a complex framework, it comes as no surprise the extremely problematic negotiation process characterizing the last decades. Several conflicts arise between countries and, as previously illustrated, the complexity of climate change may lead to several and contrasting positions on global targets, according to the criteria used to evaluate its impacts. However, during the COP21 held in Paris in December 2015, Parties finally agreed to hold temperature increase well below 2 °C. Given this ambitious target, the following Scenarios introducing the GCF are based on the GET-450.

### *4.2 The role of GCF in current climate negotiations*

An active participation of developing countries in mitigation policies is decisive to reach the global mitigation target, so that well-structured compensating schemes, such as the GCF, have become essential to reach the purpose. In order to analyze the role of the GCF in such a complex framework, the second group of simulations compares the two GCF allocation methods described in Section 3. Firstly, we focus on what happens at the global level. Accordingly, Table 8 shows a comparison between the two Scenarios in terms of emission trading equilibrium price (RCTAX) and contribution to the GCF (CTRF).

By looking at Table 8, we can see that in GCF-neg Scenario (n) the abatement cost is lower than in the alternative Scenario (*a*). This is mostly due to the larger amount of resources allocated for mitigation in China (Table 9). Mitigation resources are in fact used to finance R&D, and thus provide new and more efficient technologies that make the largest emitter country more competitive in abatement efforts, generating a lower equilibrium price. This represents an advantage also for developed countries, whose commitments become less expensive. Besides, lower abatement costs entail a reduction in carbon tax revenues directed to finance the GCF. It is worth noting that taking into consideration this kind of interactions may substantially change developed countries negotiating positions. Indeed, one of the most debated issues is the eligibility of China as a GCF resources beneficiary, strongly disapproved by USA who ask for the exclusion of China from the list of the recipient countries.

**Table 8 – ET equilibrium price (USD) and contribution to GCF (Mln USD). Comparison between GCF-neg (n) and *GCF-alt (a)***

| **RCTAX** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
|---|---|---|---|---|---|---|---|
| GCF-neg | 9 | 21 | 50 | 90 | 132 | 177 | 246 |
| *GCF-alt* | 10 | 22 | 53 | 99 | 148 | 203 | 286 |
| **CTRF** | | | | | | | |
| CAN (n) | 312 | 1,275 | 2,653 | 3,890 | 4,423 | 4,511 | 4,671 |
| *CAN (a)* | *316* | *1,313* | *2,844* | *4,434* | *5,463* | *6,126* | *7,067* |
| EU27 (n) | *1,538* | *5,933* | *12,616* | *20,030* | *25,659* | *30,627* | *39,056* |
| *EU27 (a)* | *1,559* | *6,069* | *13,161* | *21,251* | *27,269* | *31,809* | *38,259* |
| FSU (n) | 874 | 3,300 | 6,383 | 8,869 | 9,877 | 9,996 | 10,604 |
| *FSU (a)* | *871* | *3,363* | *6,835* | *10,091* | *11,846* | *12,370* | *13,141* |
| JPN (n) | 553 | 2,191 | 4,755 | 7,742 | 10,103 | 11,785 | 13,672 |
| *JPN (a)* | *561* | *2,246* | *4,966* | *8,206* | *10,769* | *12,726* | *15,290* |
| KOR (n) | 269 | 1,076 | 2,226 | 3,405 | 4,229 | 4,920 | 5,972 |
| *KOR (a)* | *272* | *1,097* | *2,322* | *3,642* | *4,597* | *5,368* | *6,526* |
| NOR (n) | 33 | 137 | 317 | 533 | 695 | 811 | 974 |
| *NOR (a)* | *33* | *141* | *337* | *586* | *786* | *933* | *1,122* |
| USA (n) | 2,603 | 9,971 | 20,263 | 29,506 | 33,096 | 32,923 | 32,759 |
| *USA (a)* | *2,640* | *10,300* | *21,861* | *33,999* | *41,537* | *45,767* | *51,351* |
| ROECD (n) | 289 | 1,144 | 2,294 | 3,379 | 3,999 | 4,332 | 4,910 |
| *ROECD (a)* | *292* | *1,171* | *2,413* | *3,677* | *4,478* | *4,940* | *5,635* |
| REU (n) | 383 | 1,620 | 3,498 | 5,412 | 6,658 | 7,592 | 9,165 |
| *REU (a)* | *389* | *1,666* | *3,710* | *5,973* | *7,655* | *9,021* | *11,048* |
| Total (n) | 6,853 | 26,646 | 55,005 | 82,765 | 98,738 | 107,498 | 121,782 |
| *Total (a)* | *6,933* | *27,366* | *58,449* | *91,860* | *114,399* | *129,060* | *149,440* |

However, as illustrated in Table 8, the allocation of mitigation resources to China would contribute to lower mitigation costs; in view of this, developed countries could benefit from allowing China to access resources and USA could reconsider its negotiating position. On the other hand, developing countries face a reduction of total amount of resources provided by the GCF in the GCF-neg Scenario. However, higher resources in GCF-alt Scenario do not necessarily mean a preference for this allocation method from the developing world: the way resources are allocated can make a difference, by influencing the preference of a country for a method over the other, on the grounds of the effects that the different allocation between adaptation and mitigation produces on the whole economy.

Tables 9 and 10 show how resources are allocated between adaptation (A) and mitigation (M) within each region. In the GCF-neg Scenario (Table 9), mitigation and adaptation resources are allocated according to GDP and vulnerability, respectively.

**Table 9 – Resources allocation in GCF-neg Scenario (Mln USD)**

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **BRA (M)** | 320 | 1,129 | 2,081 | 2,809 | 3,028 | 3,006 | 3,122 |
| ***BRA (A)*** | *60* | *230* | *469* | *695* | *816* | *873* | *971* |
| **CHN (M)** | 1,081 | 4,580 | 10,177 | 16,041 | 19,601 | 21,428 | 23,954 |
| ***CHN (A)*** | *515* | *1,941* | *3,864* | *5,605* | *6,431* | *6,724* | *7,311* |
| **IND (M)** | 349 | 1,434 | 3,168 | 5,115 | 6,564 | 7,669 | 9,262 |
| ***IND (A)*** | *618* | *2,425* | *5,057* | *7,676* | *9,226* | *10,110* | *11,512* |
| **IDN (M)** | 115 | 446 | 922 | 1,395 | 1,685 | 1,871 | 2,177 |
| ***IDN (A)*** | *89* | *345* | *707* | *1,057* | *1,252* | *1,352* | *1,515* |
| **MEX (M)** | 209 | 743 | 1,377 | 1,851 | 1,967 | 1,912 | 1,948 |
| ***MEX (A)*** | *33* | *127* | *261* | *393* | *467* | *507* | *570* |
| **EExAf (M)** | 196 | 739 | 1,500 | 2,269 | 2,782 | 3,182 | 3,876 |
| ***EExAf (A)*** | *232* | *931* | *1,994* | *3,116* | *3,870* | *4,390* | *5,189* |
| **EExAm (M)** | 172 | 613 | 1,143 | 1,565 | 1,714 | 1,732 | 1,839 |
| ***EEXAm (A)*** | *49* | *194* | *406* | *620* | *751* | *830* | *955* |
| **EExAs (M)** | 371 | 1,338 | 2,531 | 3,505 | 3,864 | 3,914 | 4,163 |
| ***EEXAs (A)*** | *117* | *469* | *1,001* | *1,550* | *1,897* | *2,117* | *2,456* |
| **DCs-Africa (M)** | 129 | 497 | 1,038 | 1,603 | 1,982 | 2,260 | 2,717 |
| ***DCs-Africa (A)*** | *837* | *3,321* | *7,021* | *10,813* | *13,204* | *14,718* | *17,068* |
| **DCs-America (M)** | 154 | 547 | 1,020 | 1,415 | 1,590 | 1,656 | 1,821 |
| ***DCs-America (A)*** | *100* | *379* | *760* | *1,112* | *1,289* | *1,363* | *1,497* |
| **DCs-Asia (M)** | 330 | 1,247 | 2,517 | 3,759 | 4,521 | 5,041 | 5,933 |
| ***DCs-Asia (A)*** | *776* | *2,958* | *5,966* | *8,762* | *10,180* | *10,775* | *11,852* |
| **Total (M)** | 3,426 | 13,313 | 27,472 | 41,327 | 49,297 | 53,671 | 60,811 |
| ***Total (A)*** | *3,426* | *13,321* | *27,507* | *41,399* | *49,384* | *53,760* | *60,897* |

Accordingly, all emerging economies but India receive most of resources for mitigation purposes. In particular, China is the country with the highest gap (24 billion USD for mitigation versus 7 billion USD for adaptation), while the high vulnerability of India makes this country eligible for more adaptation funds. As for developing countries, the energy exporters see a rather balanced resource allocation, slightly higher for mitigation. On the other hand, most of poorest and most vulnerable developing countries (DCs) see a very unbalanced allocation. However, unlike China, in this case most of resources are destined to adaptations needs.

**Table 10 – Resources allocation in GCF-alt Scenario (Mln USD)**

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **BRA (M)** | 192 | 699 | 1,358 | 1,952 | 2,239 | 2,345 | 2,532 |
| ***BRA (A)*** | *192* | *699* | *1,358* | *1,952* | *2,239* | *2,345* | *2,532* |
| **CHN (M)** | 807 | 3,348 | 7,457 | 12,003 | 15,068 | 16,887 | 19,170 |
| ***CHN (A)*** | *807* | *3,348* | *7,457* | *12,003* | *15,068* | *16,887* | *19,170* |
| **IND (M)** | 489 | 1,982 | 4,366 | 7,089 | 9,132 | 10,652 | 12,717 |
| ***IND (A)*** | *489* | *1,982* | *4,366* | *7,089* | *9,132* | *10,652* | *12,717* |
| **IDN (M)** | 103 | 406 | 866 | 1,362 | 1,702 | 1,935 | 2,265 |
| ***IDN (A)*** | *103* | *406* | *866* | *1,362* | *1,702* | *1,935* | *2,265* |
| **MEX (M)** | 122 | 448 | 873 | 1,252 | 1,420 | 1,466 | 1,564 |
| ***MEX (A)*** | *122* | *448* | *873* | *1,252* | *1,420* | *1,466* | *1,564* |
| **EExAf (M)** | 217 | 857 | 1,857 | 2,991 | 3,854 | 4,544 | 5,555 |
| ***EExAf (A)*** | *217* | *857* | *1,857* | *2,991* | *3,854* | *4,544* | *5,555* |
| **EExAm (M)** | 112 | 415 | 825 | 1,218 | 1,436 | 1,548 | 1,727 |
| ***EEXAm (A)*** | *112* | *415* | *825* | *1,218* | *1,436* | *1,548* | *1,727* |
| **EExAs (M)** | 247 | 928 | 1,877 | 2,806 | 3,339 | 3,623 | 4,065 |
| ***EEXAs (A)*** | *247* | *928* | *1,877* | *2,806* | *3,339* | *3,623* | *4,065* |
| **DCs-Africa (M)** | 488 | 1,961 | 4,282 | 6,889 | 8,796 | 10,188 | 12,133 |
| ***DCs-Africa (A)*** | *488* | *1,961* | *4,282* | *6,889* | *8,796* | *10,188* | *12,133* |
| **DCs-America (M)** | 129 | 477 | 950 | 1,411 | 1,681 | 1,829 | 2,057 |
| ***DCs-America (A)*** | *129* | *477* | *950* | *1,411* | *1,681* | *1,829* | *2,057* |
| **DCs-Asia (M)** | 560 | 2,162 | 4,513 | 6,958 | 8,531 | 9,512 | 10,933 |
| ***DCs-Asia (A)*** | *560* | *2,162* | *4,513* | *6,958* | *8,531* | *9,512* | *10,933* |
| **Total (M)** | 3,466 | 13,683 | 29,224 | 45,929 | 57,199 | 64,529 | 74,719 |
| ***Total (A)*** | *3,466* | *13,683* | *29,224* | *45,929* | *57,199* | *64,529* | *74,719* |

As for the GCF-alt Scenario (Table 10), the two criteria (GDP and vulnerability) are combined and the same amount of money is destined to mitigation and adaptation. In fact, as already mentioned, according to this allocation method, once resources are received by countries, they are balanced between mitigation and adaptation purposes.

In Table 11, we compare the two allocation methods in order to assess whether each region would face higher mitigation costs and receive more resources in the GCF-neg Scenario (positive values) or in the alternative one (negative values). As for mitigation costs, all regions would gain from the GCF-neg

Scenario except for other emerging economies that would gain in the GCF-alt Scenario starting from 2045.

**Table 11 – Allocation comparison (Mln USD)**

| | | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| China | Mitigation cost | 21 | -1128 | -5526 | -14237 | -23926 | -22800 | -7944 |
| | GCF-Mit | 274 | 1,232 | 2,720 | 4,038 | 4,533 | 4,542 | 4,784 |
| | *GFC-Ad* | *-293* | *-1408* | *-3592* | *-6398* | *-8637* | *-10162* | *-11859* |
| India | Mitigation cost | 19 | -108 | -550 | -1,616 | -3,207 | -3,473 | 4,836 |
| | GCF-Mit | -140 | -547 | -1198 | -1974 | -2568 | -2983 | -3456 |
| | *GFC-Ad* | *129* | *444* | *691* | *587* | *94* | *-541* | *-1205* |
| Other emerging | Mitigation cost | -10 | -251 | -1,359 | -4,186 | -1,175 | 15,250 | 19,371 |
| | GCF-Mit | 226 | 766 | 1282 | 1490 | 1318 | 1044 | 886 |
| | *GFC-Ad* | *-236* | *-851* | *-1660* | *-2421* | *-2826* | *-3014* | *-3305* |
| DCs-Eex | Mitigation cost | -60 | 368 | 166 | -4,395 | -19,389 | -36,971 | -38,664 |
| | GCF-Mit | 163 | 488 | 614 | 324 | -270 | -887 | -1469 |
| | *GFC-Ad* | *-177* | *-607* | *-1159* | *-1728* | *-2112* | *-2377* | *-2746* |
| DCs | Mitigation cost | 14 | -182 | -1,392 | -5,600 | -12,566 | -20,161 | -15,852 |
| | GCF-Mit | -564 | -2309 | -5170 | -8481 | -10915 | -12573 | -14653 |
| | *GFC-Ad* | *536* | *2059* | *4002* | *5429* | *5666* | *5326* | *5293* |

Differences result also in the resource allocation. DCs receive more resources for adaptation actions in the GCF-neg Scenario, while the alternative one fosters mitigation. The opposite happens for China and emerging economies. The highest differences can be seen for China and DCs. From allocation considerations, however, both regions would prefer the GCF-neg, even if for opposite reasons: as for DCs, given their high vulnerability to climate change and their scarce abatement possibilities, the allocation comparison suggests a preference for the method that fosters adaptation over mitigation, namely the GCF-neg; as for China, the same Scenario would better meet the needs of one of the biggest emitters, allocating more resources for mitigation and producing lower mitigation costs.

Nevertheless, to look at the mere allocation does not help to correctly identify the best allocation method, as it strongly depends on the impacts that the resource allocation has on the economy. Consequently, in order to analyze the impacts of the two allocation methods on developing countries, we have to focus on how resources influence the economy of receiving counties. Firstly, Table 12 shows the economic impact obtained after the introduction of the GCF mechanism. In particular, it shows GDP changes in the two GCF scenarios compared to GET-450.[32] It is worth noting that all regions always gain from the introduction of the GCF, except emerging economies that always lose and energy exporters DCs that benefit only from the GCF-alt. Among those who see an improvement in their GDP, China has the highest GDP growth, reaching over 17% in the GCF-neg Scenario as a consequence of huge amounts of resources allocated for mitigation purposes. As already mentioned, these can contribute to finance R&D and to foster the development of new technologies that can create advantages in terms of international competitiveness.

**Table 12 – GCF Impact on GDP compared to GET-450 Scenario**

| GDP change (%) | Scenarios | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| China | GCF-neg | 0.0 | 1.1 | 3.4 | 7.1 | 11.1 | 14.7 | 17.4 |
| | GCF-alt | 0.6 | 1.7 | 3.5 | 5.7 | 7.9 | 9.7 | 11.5 |
| India | GCF-neg | 0.2 | 0.7 | 1.7 | 2.8 | 3.9 | 4.3 | 4.1 |
| | GCF-alt | 0.4 | 0.8 | 1.4 | 2.0 | 2.7 | 3.2 | 3.6 |
| Other emerging | GCF-neg | 0.2 | 1.5 | 3.2 | 4.8 | 3.6 | -2.6 | -9.8 |
| | GCF-alt | -0.2 | -0.5 | -1.0 | -1.6 | -2.0 | -1.7 | -0.9 |
| DCs- Energy exporters | GCF-neg | -0.5 | -1.5 | -2.9 | -4.2 | -4.5 | -3.7 | -2.8 |
| | GCF-alt | 0.1 | 0.5 | 1.4 | 2.7 | 4.4 | 6.2 | 7.9 |
| DCs | GCF-neg | 0.0 | 0.5 | 1.2 | 2.5 | 4.2 | 6.4 | 7.8 |
| | GCF-alt | 0.0 | 0.2 | 0.4 | 0.8 | 1.4 | 2.2 | 3.2 |

This can also explain GDP losses in other emerging economies and energy exporters developing countries. More precisely, although the highest resources allocated for mitigation in the GCF-neg, both regions register the worst loss in this Scenario. The advantages deriving from this resource allocation faded by what happens to the world's leader, namely China: as China's exports represent about 12% of world trade[33], its higher competitiveness on global markets prejudice other economies, especially those which play a role in international markets.

In addition to GDP changes, Table 13 shows GCF impacts in terms of welfare change compared to BAU. In this case all countries except for emerging economies benefit from the GCF. The group of Other emerging, in fact, register a sharp welfare reduction in the GCF-neg Scenario.

**Table 13 – GCF Impact on EV compared to GET-450 Scenario**

[32] GDP takes into account both climate change costs (-) and adaptation resources (+).
[33] Source: CIA, The World Factbook. 2015 Estimates

| EV change (%) | Scenarios | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| China | GCF-neg | -0.36 | 2.97 | 9.06 | 17.55 | 26.44 | 34.50 | 45.19 |
| | GCF-alt | 1.47 | 4.11 | 7.76 | 12.31 | 17.13 | 22.20 | 31.95 |
| India | GCF-neg | -0.96 | 0.91 | 3.20 | 5.53 | 7.12 | 6.63 | 3.88 |
| | GCF-alt | 0.94 | 1.01 | 1.91 | 3.78 | 5.82 | 7.15 | 8.34 |
| Other emerging | GCF-neg | 6.06 | 16.47 | 25.12 | 25.64 | -21.13 | -108.84 | -141.61 |
| | GCF-alt | -1.06 | -2.21 | -2.83 | -2.59 | 1.48 | 9.15 | 18.03 |
| DCs- Energy exporters | GCF-neg | -4.71 | -9.37 | -17.51 | -22.99 | -11.47 | 8.59 | 7.85 |
| | GCF-alt | 1.21 | 4.84 | 11.36 | 18.74 | 23.45 | 21.29 | 18.16 |
| DCs | GCF-neg | 0.98 | 10.06 | 14.82 | 23.02 | 29.62 | 33.52 | 27.16 |
| | GCF-alt | 0.65 | 4.62 | 7.68 | 12.26 | 14.86 | 17.43 | 21.32 |

This is mostly due to a lower amount of money received compared to the GCF-alt Scenario (10304 Mln USD vs 12723 Mln USD in 2050), especially for Brazil (4092 Mln USD vs 5064 in 2050).[34] With the current allocation mechanism (GCF-neg), 50% of adaptation resources must be directed to LDCs. This means that Brazil, as an emerging economy, can not benefit from such a preferential channel. Nevertheless, the presence of the Amazon rainforest makes Brazil one of the countries that mostly need resources to cope with climate change, especially REDD+ resources. It is then clear that, as already stated in past qualitative results (Costantini et al., 2016), the preference of a country for an allocation method is influenced by its characteristics and priorities. Therefore, several aspects must be taken into consideration to design an efficient compensatory mechanism. In this regard, simulation results give some elements to strengthen the discussion about the GCF rules on a quantitative basis, deducing the preferences of countries between the two allocation methods. China and DCs, clearly prefer the current structure of the GCF (GCF-neg), as they would benefit both in terms of welfare and GDP growth. Energy exporters developing countries and the group of "Other emerging", by contrast, prefer the GCF-alt Scenario. For India, on the other hand, the situation is less clear. In fact it may seem that the GDP growth associated to the GCF-neg Scenario (Table 12) would make it more advantageous. However, alternative allocation rules yield a higher level of welfare, so that this choice might represent a difficult trade-off between welfare and economic growth.

Finally, Table 14 is an attempt to investigate which of the four policy scenarios can represent the best option today in terms of welfare. In accordance with Table 5, a 4% discount rate is applied.

[34] See Tables 9 and 10.

**Table 14 – Welfare change compared to BAU**

| EV change | GET-450 | GET-550 | GCF-neg | GCF-alt |
|---|---|---|---|---|
| **Developed** | -1,697,529 | -58,783 | -4,306,695 | -1,901,807 |
| **CHN** | -924,687 | 37,080 | 798,256 | 338,367 |
| **IND** | 1,249,841 | 543,656 | 1,440,109 | 1,453,890 |
| **Other emerging** | 57,169 | 130,896 | -126,074 | 72,291 |
| **DCs-Eex** | -303,414 | 253,857 | -427,903 | -102,780 |
| **DCs** | 1,236,702 | 919,820 | 1,644,233 | 1,473,702 |
| **World** | -381,918 | 1,826,526 | -978,074 | -31,435,878 |

Today, the GET-550 seems to be the favourite Scenario at global level, as well as the GCF-neg once the GCF is introduced. Moreover, whatever the allocation method could be, all developing regions would benefit from the GCF. The only exceptions are other emerging economies that would gain only in the GCF-alt Scenario and the energy exporters. Once again, however, results stress how the preference for a policy scenario over the others strongly depends on the evaluation method applied. If we look at the two GCF Scenarios, we can see that developed countries would prefer the GCF-alt in terms of welfare change (Table 14). However, as illustrated in Table 8, they would face lower mitigation costs under the GCF-neg Scenario. As previously stated, there may be disputes also among developing countries to define the best GCF allocation rules. Indeed, this analysis confirms that the preference of a country for an allocation method is strongly influenced by its characteristics and needs. Consequently, the definition of country-specific GCF allocation rules is crucial to design an effective compensating mechanism and to facilitate the negotiating process.

## 5. Conclusions

This paper represents an attempt to investigate the dynamics arising in climate negotiations by taking into account the cost of climate change. The study is carried out through the development of a CGE model by simulating several scenarios. The first results show that the introduction of the cost of climate change in costs-benefits evaluations may strongly influence countries' behavior towards mitigation actions. In particular, as developing countries are those who face the highest climate costs, they may benefit from actively participating in mitigation policies. Defining the stringency of the global mitigation target (450 ppm vs 550 ppm) as well as the best structure of compensating mechanisms

(GCF-neg vs GCF-alt) is more complicated. With this regard, it is worth noting that the purpose of this paper is not to provide a solution to reach an effective agreement but rather to stress the complex dynamics behind the decision making and the negotiation processes. Indeed, climate change policies affect many aspects of a country's economy, such as welfare and GDP. The shift from a policy evaluation criterion to another can lead to several and often contrasting conclusions. In view of this, it is not surprising that reaching a global agreement is a so demanding challenge. However, a well-structured GCF can certainly play a crucial role. In this respect, the analysis above confirms the urgency to design it in order to meet countries' needs and priorities. Given the heterogeneity of developing countries as well as the several ways the GCF can impact receiving countries, the policy advise arising from this study is to design a well structured country-specific GCF. This would contribute to persuading developing countries to actively participate in mitigation policies as well as to facilitating negotiation processes. Indeed, as the UNFCCC works with the "one country one vote" rule and given the high number of developing countries, a country-specific GCF may contribute to providing benefits to many countries, thus fostering their active involvement in the fight against climate change.

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## Appendix A

### Table A1: DARA indicators

| OVERALL INDEX | SUB-INDEX | INDICATORS |
|---|---|---|
| Aggregation of sub-indexes | Habitat Change | • Biodiversity<br>• Desertification<br>• Heating and Cooling<br>• Labour Productivity<br>• Permafrost<br>• Sea-level Rise<br>• Water |
| | Health Impact | • Diarrheal Infections<br>• Heat & Cold Illnesses<br>• Hunger<br>• Malaria & Vector-borne<br>• Meningitis |
| | Industry Stress | • Agriculture<br>• Fisheries<br>• Forestry<br>• Hydro Energy<br>• Tourism<br>• Transport |
| | Environmental Disasters | • Floods and landslides<br>• Storms<br>• Wildfires<br>• Drought |

Source: DARA (2012), Methodological Documentation For The Climate Vulnerability Monitor 2nd Edition, p. 7

### Table A2: Ranges of global mean temperature increase (°C) above pre-industrial temperatures for different levels of $CO_2$ equivalent concentrations (ppm)

| Equivalent CO2 (ppm) | Best Guess | Very likely above | Likely in the range |
|---|---|---|---|
| 350 | 1 | 0.5 | 0.6-1.4 |
| 450 | 2.1 | 1 | 1.4-3.1 |
| 550 | 2.9 | 1.5 | 1.9-4.4 |
| 650 | 3.6 | 1.8 | 2.4-5.5 |
| 750 | 4.3 | 2.1 | 2.8-6.4 |
| 1000 | 5.5 | 2.8 | 3.7-8.3 |
| 1200 | 6.3 | 3.1 | 4.2-9.4 |

Source: IPCC Fourth Assessment Report, WG I, Chapter 10, Table 10.8

### Table A3 - List of GDynE countries

| GTAP code | Code | Country | GTAP code | Code | Country | GTAP code | Code | Country |
|---|---|---|---|---|---|---|---|---|
| BRA | bra | Brazil | EU27 | mlt | Malta | RAM | gtm | Guatemala |
| CAN | can | Canada | EU27 | nld | Netherlands | RAM | hnd | Honduras |
| CHN | chn | China | EU27 | pol | Poland | RAM | nic | Nicaragua |
| CHN | hkg | Hong Kong | EU27 | prt | Portugal | RAM | pan | Panama |
| EExAf | xcf | Central Africa | EU27 | rou | Romania | RAM | pry | Paraguay |
| EExAf | egy | Egypt | EU27 | svk | Slovakia | RAM | per | Peru |
| EExAf | nga | Nigeria | EU27 | svn | Slovenia | RAM | xca | Rest of Central America |
| EExAf | xnf | Rest of North Africa | EU27 | esp | Spain | RAM | xna | Rest of North America |
| EExAf | zaf | South Africa | EU27 | swe | Sweden | RAM | xsm | Rest of South America |
| EExAf | xac | South Central Africa | EU27 | gbr | United Kingdom | RAM | ury | Uruguay |
| EExAm | arg | Argentina | FSU | blr | Belarus | RAS | arm | Armenia |
| EExAm | bol | Bolivia | FSU | rus | Russian Federation | RAS | bgd | Bangladesh |
| EExAm | col | Colombia | IDN | idn | Indonesia | RAS | bhr | Bharain |
| EExAm | ecu | Ecuador | IND | ind | India | RAS | khm | Cambodia |
| EExAm | ven | Venezuela | JPN | jpn | Japan | RAS | kgz | Kyrgyztan |
| EExAs | aze | Azerbaijan | KOR | kor | Korea | RAS | lao | Lao People's Democr. Rep. |
| EExAs | irn | Iran Islamic Republic | MEX | mex | Mexico | RAS | mng | Mongolia |
| EExAs | kaz | Kazakhstan | NOR | nor | Norway | RAS | npl | Nepal |
| EExAs | kwt | Kuwait | RAF | bwa | Botswana | RAS | xea | Rest of East Asia |
| EExAs | mys | Malaysia | RAF | cmr | Cameroon | RAS | xoc | Rest of Oceania |
| EExAs | omn | Oman | RAF | civ | Cote d'Ivoire | RAS | xsa | Rest of South Asia |
| EExAs | qat | Qatar | RAF | eth | Ethiopia | RAS | xse | Rest of Southeast Asia |
| EExAs | xsu | Rest of Former Soviet Union | RAF | gha | Ghana | RAS | sgp | Singapore |
| EExAs | xws | Rest of Western Asia | RAF | ken | Kenya | RAS | lka | Sri Lanka |
| EExAs | sau | Saudi Arabia | RAF | mdg | Madagascar | RAS | twn | Taiwan |
| EExAs | are | United Arab Emirates | RAF | mwi | Malawi | RAS 2 | pak | Pakistan |
| EU27 | aut | Austria | RAF | mus | Mauritius | RAS 2 | phl | Philippines |
| EU27 | bel | Belgium | RAF | moz | Mozambique | RAS 2 | tha | Thailand |
| EU27 | bgr | Bulgaria | RAF | nam | Namibia | REU | alb | Albania |
| EU27 | cyp | Cyprus | RAF | xec | Rest of Eastern Africa | REU | hrv | Croatia |
| EU27 | cze | Czech Republic | RAF | xsc | Rest of South African Custom | REU | geo | Georgia |
| EU27 | dnk | Denmark | RAF | xwf | Rest of Western Africa | REU | xee | Rest of Eastern Europe |
| EU27 | est | Estonia | RAF | sen | Senegal | REU | xef | Rest of EFTA |
| EU27 | fin | Finland | RAF | tza | Tanzania | REU | xer | Rest of Europe |
| EU27 | fra | France | RAF | uga | Uganda | REU | xtw | Rest of the World |
| EU27 | deu | Germany | RAF | zmb | Zambia | REU | tur | Turkey |
| EU27 | grc | Greece | RAF | zwe | Zimbabwe | REU | ukr | Ukraine |
| EU27 | hun | Hungary | RAF 2 | mar | Morocco | ROECD | aus | Australia |
| EU27 | irl | Ireland | RAF 2 | tun | Tunisia | ROECD | isr | Israel |
| EU27 | ita | Italy | RAM | xcb | Caribbean | ROECD | nzl | New Zealand |
| EU27 | lva | Latvia | RAM | chl | Chile | ROECD | che | Switzerland |
| EU27 | ltu | Lithuania | RAM | cri | Costa Rica | USA | usa | United States of America |
| EU27 | lux | Luxembourg | RAM | slv | El Salvador | VNM | vnm | Vietnam |

### Table A4 - List of GDYnE Regions

| GTAP code | Description |
|---|---|
| CAN | Canada |
| EU27 | European Union |
| FSU | Former Soviet Union |
| JPN | Japan |
| KOR | Korea |
| NOR | Norway |
| USA | United States |
| ROECD | Rest of OECD |
| BRA | Brazil |
| CHN | China |
| IND | India |
| IDN | Indonesia |
| MEX | Mexico |
| EExAf | African Energy Exporters |
| EExAm | American Energy Exporters |
| EExAs | Asian Energy Exporters |
| RAF | Rest of Africa |
| RAF2 | Rest of Africa 2 |
| RAM | Rest of America |
| RAS | Rest of Asia |
| RAS 2 | Rest of Asia 2 |
| VNM | Vietnam |
| REU | Rest of Europe |

### Table A5 - List of GDYnE aggregates

| Sector | Description |
|---|---|
| agri | Agriculture |
| food | Food |
| coal | Coal |
| oil | Oil |
| gas | Gas |
| oil_pcts | Petroleum, coal products |
| electricity | Electricity |
| text | Textile |
| nometal | Non-metallic mineral products |
| wood | Wood |
| paper | Pulp and paper |
| chem | Chemical and petrochemical |
| basicmet 1 | Basic metal 1 |
| basicmet 2 | Basic metal 2 |
| transeqp | Transport equipment |
| macheqp | Machinery and equipment |
| oth_man_ind | Other manufacturing industries |
| transport | Transport |
| wat_transp | Water Transport |
| air_transp | Air Transport |
| services | Services |

**Table A6 - List of GDYnE commodities and aggregates**

| Sector | Code | Products | Sector | Code | Products |
|---|---|---|---|---|---|
| agri | pdr | paddy rice | wood | lum | wood products |
| agri | wht | wheat | paper | ppp | paper products, publishing |
| agri | gro | cereal grains nec | oil_pcts | p_c | petroleum, coal products |
| agri | v_f | vegetables, fruit, nuts | chem | crp | chemical, rubber, plastic products |
| agri | osd | oil seeds | nometal | nmm | mineral products nec |
| agri | c_b | sugar cane, sugar beet | basicmet 1 | i_s | ferrous metals |
| agri | pfb | plant-based fibers | basicmet 1 | nfm | metals nec |
| agri | ocr | crops nec | basicmet 2 | fmp | metal products |
| agri | ctl | bovine cattle, sheep and goats, horses | transeqp | mvh | motor vehicles and parts |
| agri | oap | animal products nec | transeqp | otn | transport equipment nec |
| agri | rmk | raw milk | macheqp | ele | electronic equipment |
| agri | wol | wool, silk-worm cocoons | macheqp | ome | machinery and equipment nec |
| agri | frs | forestry | oth_man_ind | omf | manufactures nec |
| agri | fsh | fishing | electricity | ely | electricity |
| Coal | coa | coal | gas | gdt | gas manufacture, distribution |
| Oil | oil | oil | services | wtr | water |
| Gas | gas | gas | services | cns | construction |
| nometal | omn | minerals nec | services | trd | trade |
| food | cmt | bovine cattle, sheep and goat meat products | transport | otp | transport nec |
| food | omt | meat products | wat_transp | wtp | water transport |
| food | vol | vegetable oils and fats | air_transp | atp | air transport |
| food | mil | dairy products | services | cmn | communication |
| food | pcr | processed rice | services | ofi | financial Oth_Ind_serices nec |
| food | sgr | sugar | services | isr | insurance |
| oth_man_ind | ofd | Oth_Ind_ser products nec | services | obs | business and other services nec |
| food | b_t | beverages and tobacco products | services | ros | recreational and other services |
| textile | tex | textiles | services | osg | public admin. and defence, education, health |
| textile | wap | wearing apparel | services | dwe | ownership of dwellings |
| textile | lea | leather products | | | |

## Appendix B

### Table B1 – Cost of climate change in BAU (Mln USD)

| CCR | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 121,635 | 156,663 | 197,103 | 253,269 | 320,613 | 414,356 | 532,346 |
| **CHN** | 233,084 | 299,692 | 375,090 | 477,840 | 597,175 | 757,822 | 951,618 |
| **IND** | 297,316 | 400,476 | 525,085 | 700,941 | 917,637 | 1,218,602 | 1,598,291 |
| **Other emerging** | 85,411 | 113,118 | 145,916 | 191,613 | 246,700 | 322,227 | 416,008 |
| **DCs-Eex** | 197,187 | 271,946 | 365,462 | 500,591 | 673,507 | 921,106 | 1,246,280 |
| **DCs** | 465,523 | 643,198 | 866,427 | 1,188,917 | 1,601,820 | 2,193,395 | 2,971,860 |
| **World** | 1,400,157 | 1,885,093 | 2,475,084 | 3,313,171 | 4,357,452 | 5,827,507 | 7,716,403 |

### Table B2 – Climate change impact on GDP per region in BAU (%)

| CCR (% GDP) | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **CAN** | 0.14 | 0.17 | 0.21 | 0.25 | 0.29 | 0.36 | 0.44 |
| **EU27** | 0.18 | 0.21 | 0.25 | 0.31 | 0.37 | 0.46 | 0.56 |
| **FSU** | 1.11 | 1.24 | 1.37 | 1.57 | 1.81 | 2.19 | 2.66 |
| **JPN** | 0.24 | 0.28 | 0.33 | 0.41 | 0.50 | 0.62 | 0.77 |
| **KOR** | 0.35 | 0.40 | 0.45 | 0.54 | 0.64 | 0.78 | 0.95 |
| **NOR** | 0.06 | 0.07 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 |
| **USA** | 0.12 | 0.15 | 0.18 | 0.21 | 0.26 | 0.31 | 0.38 |
| **ROECD** | 0.17 | 0.20 | 0.24 | 0.29 | 0.35 | 0.43 | 0.52 |
| **REU** | 1.35 | 1.50 | 1.66 | 1.91 | 2.21 | 2.64 | 3.15 |
| **BRA** | 1.15 | 1.30 | 1.45 | 1.67 | 1.92 | 2.26 | 2.65 |
| **CHN** | 2.15 | 1.94 | 1.78 | 1.74 | 1.74 | 1.85 | 2.01 |
| **IND** | 9.23 | 8.94 | 8.53 | 8.42 | 8.34 | 8.60 | 9.01 |
| **IDN** | 4.35 | 4.43 | 4.45 | 4.61 | 4.77 | 5.07 | 5.40 |
| **MEX** | 0.95 | 1.07 | 1.21 | 1.43 | 1.69 | 2.05 | 2.49 |
| **EExAf** | 7.84 | 8.57 | 9.11 | 9.84 | 10.47 | 11.32 | 12.08 |
| **EExAm** | 2.04 | 2.34 | 2.65 | 3.10 | 3.61 | 4.30 | 5.13 |
| **EExAs** | 2.23 | 2.56 | 2.90 | 3.40 | 3.97 | 4.78 | 5.75 |
| **DCs-Africa** | 23.49 | 25.52 | 26.79 | 29.10 | 31.33 | 34.75 | 38.33 |
| **DCs-America** | 2.24 | 2.56 | 2.88 | 3.27 | 3.66 | 4.19 | 4.77 |
| **DCs-Asia** | 7.35 | 7.81 | 8.12 | 8.63 | 9.05 | 9.69 | 10.35 |
| **World** | 1.70 | 1.96 | 2.21 | 2.57 | 2.94 | 3.47 | 4.08 |

### Table B3 – Regional cost of climate change in GET-450 (Mln USD)

| CCR | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Developed** | 119,732 | 139,417 | 143,078 | 142,505 | 140,761 | 138,168 | 136,114 |
| **CHN** | 229,434 | 266,736 | 272,334 | 268,946 | 262,255 | 252,850 | 243,411 |
| **IND** | 292,660 | 356,438 | 381,237 | 394,516 | 402,988 | 406,591 | 408,822 |
| **Other emerging** | 84,073 | 100,679 | 105,942 | 107,847 | 108,340 | 107,512 | 106,409 |
| **DCs-Eex** | 194,099 | 242,041 | 265,343 | 281,752 | 295,776 | 307,330 | 318,782 |
| **DCs** | 458,233 | 572,470 | 629,067 | 669,168 | 703,453 | 731,834 | 760,163 |
| **World** | 1,378,232 | 1,677,782 | 1,797,002 | 1,864,735 | 1,913,574 | 1,944,284 | 1,973,702 |

### Table B4 –Policy vs BAU. Comparison between GET450 and GET-550 (Discount rate: 2%)

| | GET-450 vs BAU | | GET-550 vs BAU | |
|---|---|---|---|---|
| | **Net discounted benefits** | **Total EV (discounted)** | **Net discounted benefits** | **Total EV (discounted)** |
| **Developed** | -539,895 | -2,827,356 | 124,494 | -91,476 |
| **China** | 178,017 | -1,454,301 | 295,067 | 122,336 |
| **India** | 948,111 | 2,125,992 | 527,692 | 939,962 |
| **Other emerging** | 171,836 | 60,378 | 137,920 | 213,789 |
| **DCs-Eex** | 363,161 | -413,306 | 383,743 | 460,568 |
| **DCs** | 1,615,717 | 2,118,871 | 934,680 | 1,587,605 |
| **World** | 2,737,131 | -389,723 | 2,403,741 | 3,232,783 |

### Table B5 – Policy vs BAU. Comparison between GET450 and GET-550 (Discount rate: 6%)

| | GET-450 vs BAU | | GET-550 vs BAU | |
|---|---|---|---|---|
| | **Net discounted benefits** | **Total EV (discounted)** | **Net discounted benefits** | **Total EV (discounted)** |
| **Developed** | -539,895 | -1,048,156 | 124,494 | -38,588 |
| **China** | 178,017 | -610,140 | 295,067 | -2,580 |
| **India** | 948,111 | 756,317 | 527,692 | 323,195 |
| **Other emerging** | 171,836 | 49,503 | 137,920 | 83,035 |
| **DCs-Eex** | 363,161 | -225,300 | 383,743 | 141,685 |
| **DCs** | 1,615,717 | 743,753 | 934,680 | 548,602 |
| **World** | 2,737,131 | -334,024 | 2,403,741 | 1,055,348 |