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# *Climate change and developing countries*

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## Contents

## Introduction

Climate change is one of the greatest challenges the world is facing. Nevertheless, its impacts are not uniformly distributed: developing countries are those which suffer the most. In other words, they are the most vulnerable to climate change, even though they are not responsible for it. Based on this paradox, the Common But Differentiated Responsibilities Principle (CBDR) represents the core principle of the current climate regime: the Kyoto Protocol (KP). It states that "[t]he Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof" (Art. 3.1). Consequently, at the beginning of climate debate the main objective was to get Annex I countries to ratify the KP whereas developing country concerns remained marginal. However, last years have been characterized by an increasing role of developing countries both in emission levels and climate negotiations. Indeed, during the current negations to define a new climate regime to be implemented in 2020, the attention devoted to developing countries' interests results in several decisions concerning both adaptation and mitigation (NAMAs, NAPs, Green Climate Fund, Technology Transfer Mechanism). Moreover, the share of GHG emissions by developing countries, and in particular emerging economies, is expected to substantially increase in the future. This has exacerbated the debate about the CBDR Principle, considering how crucial active involvement of the developing part of the world is in climate actions. In this regard, the Paris Agreement, reached last December during the 21st Conference of the Parties (COP21), is still based on the principles of equity and CBDR but represents a timid step forward towards a burden sharing involving all countries. Indeed, it states that "Developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets" while "developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances" (Art. 4.4).

In the light of the foregoing considerations, the research project aims to investigate how the role of developing countries in the fight against climate change has been changing over time. The research consists of three papers. The first one investigates the role of developing countries in the Kyoto Protocol first commitment period (2008-2012) and, in particular, the focus is on the Clean Development Mechanism (CDM), the only instrument that directly involves them. The second paper analyzes the role of these countries in post 2012 negotiations, with particular emphasis on the role that their heterogeneity plays in the formation of coalitions and in the negotiation process. Finally, the third one investigates costs and benefits of ongoing climate negotiations and the role that a compensatory measure specifically designed to meet developing countries' needs can have in fostering the realization of a more effective climate agreement.

# Do bilateral commercial relationships influence the distribution of CDM projects?

## 1. Introduction

Climate change is recognised as one of the greatest environmental, social and economic threats facing the world. It is a phenomenon that influences all countries, from the most industrialised to the poorest ones, and affects several aspects of daily life. For this reason, the debate on climate change has increased in recent years as well as international efforts to combat this threat. In 1994, the UNFCCC (United Nation Framework Convention on Climate Change) entered into force with the aim of achieving the "*stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*" (art. 2).

The instrument used to achieve this goal is the Kyoto Protocol (KP) which was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The Protocol divides countries into Annex I and Non-Annex I parties, broadly corresponding to industrialised and developing countries. In this regard it is worth noting that developing countries that constitute the Non-Annex I parties are a very heterogeneous group, which includes emerging economies as well as least developed countries.

Since the Kyoto Protocol recognises that developed countries are mainly responsible for the current concentration of greenhouse gas (GHG) emissions in the atmosphere as a result of more than 150 years of industrial activity, it exclusively commits Annex I countries to reduce their emissions in accordance with the principle of common but differentiated responsibilities. The overall goal is to achieve the reduction of GHG emissions to an average of 5.2% compared with 1990 levels over the implementation period 2008-2012.

Under the KP, developed countries must meet their targets primarily through national measures. However, there are also additional tools available for reaching domestic targets represented by Flexible Mechanisms: Emission Trading (ET), Joint Implementation (JI) and the Clean Development Mechanism (CDM).

Despite the fact that the first commitment period (2008–2012) of the KP has already passed, the Parties are still discussing what the future of the KP will be. During the 17th Conference of Parties (COP 17), held in Durban in December 2011, the Parties agreed on a set of issues including the implementation of the Green Climate Fund (GCF). The GCF aims to help developing countries cope with climate change, in particular by fostering the diffusion of clean technologies. However, the most important agreement reached during the COP 17 was the deal known as the "Durban Platform for Enhanced Action" in which Parties agreed on the extension of the KP for a second commitment period lasting from 2013 to 2020 (although some countries such as Canada, Japan and Russia did not sign it). Parties will also create a new international treaty by 2015, which should be operational in 2020. Most importantly, this new treaty will contain legally binding commitments for all countries. Moreover, developed countries ask for greater involvement of emerging economies such as Brazil, China and India, in the fight against climate change. So far, these countries have been considered as developing countries and, for this reason, they do not have commitments under the Protocol.

Indeed, at present, the only instrument that also involves developing countries is the CDM. It allows a country with an emission reduction commitment to implement an abatement project in developing countries. These projects can earn Certified Emission Reduction (CER) credits, one of which is equivalent to one ton of $CO_2$ ($tCO_2e$), that can be used by industrialised countries to meet their emission reduction targets under the KP, can be banked for future commitments or can be traded on the carbon market.

The main characteristic of the CDM is related to the fact that it was created in order to achieve a dual purpose: (i) lower the overall cost of reducing GHG emissions released to the atmosphere, giving industrialised countries some flexibility in how they meet their emission reduction targets; (ii) stimulate a sustainable development path in developing countries (Art. 12 of the KP).

As such, the CDM presents a great opportunity for developing countries (especially Least Developed Countries, LDCs), in that hosting a project can both start a new development path and increase a country's participation in the international forum. This dual objective requires that both goals should be achieved without necessarily giving preference to one over the other. In other words, whether cost efficiency or sustainable development is the leading objective should be a matter of choice for the investing partners.

Despite the dual aims of the CDM, the geographical distribution of CDM projects has so far been very uneven, and the goal of fostering a sustainable development path in the least developed economies appears to have been less important than considerations regarding the cost efficiency of such abatement projects. Approximately 70% of registered CDM projects have only been implemented in just three countries - Brazil, China, and India - with only 1.6% of projects implemented in Sub-Saharan Africa. This means that even if the CDM was created to direct investment flows to the poorest developing countries, most of the investments are concentrated in emerging economies and have ignored those countries that need them the most. Thus, we are dealing with a paradox since the richest developing countries are those that benefit the most from this mechanism.

The uneven distribution of projects represents one of the major shortcomings of the CDM. However, there have only been a few analyses in the literature that have sought to delineate the causes of this. So far most of literature has focused on (i) the ability of CDM projects to create sustainable development in host countries, (ii) the capacity to reduce abatement costs in investing countries and (iii) the actual effect of technology transfer (TT) from rich countries to poor economies.

With regard to the first point, we must bear in mind that sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987) and is characterised by the fact that it encompasses the three dimensions of environment, society and economy. This means that CDM projects promote sustainable development if they contribute to the improvement of the economic, environmental and social conditions of host countries and they can only be implemented if the Designated National Authority (DNA) recognises that they meet the sustainability criteria set by developing countries.[1] For this reason, we need to know which criteria are considered the most important ones.

For example Brent *et al.* (2005) conducted an analysis in order to investigate the main sustainability criteria that a CDM project should respect in the context of South Africa from industry and national government perspectives. This study indicates three main aspects, one for each sustainable dimension: capacity development (training and skills development of project participants and beneficiaries) is

[1] The registration of a proposed CDM project activity can only take place once approval letters are obtained from the DNA of each Party involved, including confirmation by the host Party that the project activity helps it to achieve sustainable development (3/CMP.1, Annex, paragraph 40(a)).

recognised as the most important social criterion; water resources (water availability and use, human health impacts etc.) is the most important environmental criterion and the macroeconomic benefits criterion (employment creation, poverty alleviation, increase in export potential etc.) is emphasised as the most important for the economic dimension of sustainable development.

With regard to the second issue concerning abatement cost reductions, it should be stressed that, although the CDM in principle offers a suite of potential contributions to sustainable development (Boyd *et al.*, 2009), recent studies suggest that the CDM's contribution to local sustainable development has been limited (Olsen, 2007; Sutter and Parreño, 2007). In particular, Sutter and Parreño (2007) analyse the first 16 registered CDM projects to see whether a trade-off between objectives exists. They compare their contribution in terms of emission reductions and sustainable development, measured by three components: local employment generation, the distribution of carbon revenue and local air quality effects. They find a strong contrast that shows how the trade-off is strongly in favour of the cost-efficient emission reduction objective (95.7% of CERs) but neglects the sustainable development objective.

The third aspect related to the CDM that has been widely discussed is represented by its contribution in terms of technology transfer. In fact, although the primary objective of the CDM was not explicitly related to technology transfer, transfer is seen as an important indirect consequence of it. The participation of communities in the implementation of CDM projects can enhance local capacity by starting a process of 'learning by doing', which can lead to higher levels of 'know-how', education, and the creation of employment. In this way, projects can contribute to a structural change in terms of innovative activity, considered as a major channel through which technological capabilities may lead to better competitiveness performance (see, among others, Montobbio and Rampa, 2005).

However, according to Millock (2002), TT in the CDM context can act as an incentive for cost-effective emissions reductions under bilateral CDM contracts when there is asymmetric information between the investor and the host party. In other words, it provides a motivation that counterbalances any incentives to cheat on emission reductions. In the absence of TT, the host country (i.e. the agent) would have an incentive to exaggerate the emission reduction costs in order to receive a higher compensatory transfer payment,[2] whereas, with the technology transfer included, overstating this cost means that the value of

[2] According to Rose et al. (1999), one policy priority is to design transfer payments in order to compensate for the

the technology for the developing country is emphasized and the agent's original incentives not to reveal the actual costs are partially counterbalanced.

Finally, of the studies conducted in order to investigate the actual role of the CDM in determining the extent of the transfer of technologies, an example is represented by Haščič and Johnstone (2011), in the field of wind power. They find that the direct contemporaneous effect of the CDM has a positive influence on the transfer between Annex I and Non-Annex I countries whereas, if the cumulative stock of projects is taken into account, the effect is negative. This happens because the implementation of CDM also has an effect on absorptive capacity for host countries so that, according to this study, measures to encourage both technology transfer and domestic innovation capacity should be complementary.

However, the issue related to the relationship between the CDM and the creation and transfer of technology is very controversial especially because using the CDM as a tool to achieve multiple purposes can lead to outcomes that are sometimes conflicting (Bosetti *et al.,* 2011).[3]

Although the CDM has been widely investigated in recent years, as already mentioned, little attention has been paid to one of its greatest shortcomings: the uneven distribution of projects.

The purpose of this work is to rectify this lack. The main research question here is whether the distribution of CDM investments can be explained by the existence of a well-established bilateral relationship between developed and developing countries. In Section 2, some of the previous literature is considered and a description of some stylized facts concerning the implementation and distribution of CDM projects is provided. Section 3 provides a description of the dataset and empirical methodology used in this analysis. The empirical results gleaned by the econometric estimations are discussed in Section 4. It is concluded in Section 5 that cost-effectiveness as a criterion for abatement efforts has not been the only driving force influencing the decision on destination markets and that bilateral export flows from Annex I economies towards non-Annex I countries explain a large portion of the geographical distribution

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fact that if, at a later time, the host countries will be subject to a binding emission reduction target, only more expensive options of abatement will remain.

[3] According to Bosetti *et al.* (2011), for example, the effect of reducing emissions from deforestation (RED) on energy technology R&D and low-carbon technology investments follows two channels: on the one hand, RED makes it possible to reach the policy target with less emission reduction so that investments in the development of new technologies decrease; on the other hand, RED affects technology investments through the impact on fossil fuel prices: since RED allows greater flexibility in reducing fossil fuel consumption, the prices of fossil fuels are higher under the RED than under no-RED policy scenarios and this increases the relative profitability of investments in alternative carbon-free technologies.

of CDM projects. Some policy recommendations are also offered.

## 2. Implementation and distribution of CDM projects

### *2.1. Literature review*

Several factors have been identified in the literature as determinants of the distribution of CDM projects. According to Jung (2005), three factors explain what makes host countries attractive to investing countries and thus the distribution of projects: the emission reduction potential, the general investment environment and the institutional capacity. The latter is particularly important: a country can only host a CDM project if it has ratified the KP and if it has an operating DNA. A host country must also indicate the development priorities that Annex I (i.e. developed) countries should take into account in their projects. As it is, not all developing countries have the experience and the institutional capacity to satisfy these requirements. Foreign direct investment (FDI) flows have also been recognized to be a main factor in attracting CDM projects to host countries. As Desanker (2005) has argued, the lack of FDI in African countries is one of the main reasons why African countries have not attracted many CDM projects. A deeper analysis is carried out by Winkelman and Moore (2011) who develop a probit model that aims to investigate which aspects of developing countries can be considered as attractors of CDM projects where the dependent variable represents binary information about whether a country has hosted projects or not. According to this study, the main factors that contribute to determining the distribution of projects across Non-Annex I countries are represented by the presence of a high level of overall emissions, domestic human capital and a growing electricity sector in host countries. In this case, the level of emissions is considered as the main determinant for CDM distribution: the higher the GHG emissions, the higher the potential for profitable projects by exploiting competitive abatement cost conditions.

Wang and Firestone (2010) also consider GHG emission levels (both in developed and developing countries) as the primary determinant of CDM projects. By relying on a modified gravity model, they build an econometric model in order to investigate the relevance of some aspects that could explain CDM distribution. The most robust findings relate to the role played by GHG emissions since CDM permits are positively correlated to total emissions of host and investing countries and inversely proportional to the geographic distance. In addition, they also investigate some factors that influence transaction costs such as distance, project size, the existence of good infrastructure and the degree of openness of developing countries as well as specific relationships between host and developed country such as a common language or the existence of past colonial relationships.

According to Wang and Firestone (2010), specific emphasis is also given to the degree of openness of host countries to international markets, as a sign of a broad capability to maintain external relationships and reduce transaction costs. Nevertheless, they only considered the level of international trade unilaterally from the perspective of host countries and, indeed, trade-related bilateral relationships were ignored.

In order to fill this gap, in this study the role of trade bilateral relationships is explicitly modeled by modelling a gravity equation where export flows from each investor to each host country are accounted for among the explanatory variables. More specifically, as already mentioned, the research question is if and to what extent the distribution of CDM investments can be explained by the existence of a well-established bilateral relationship (existing trade flows) as a privileged channel of international relationships.

Two ancillary research questions are also tested. Firstly, by considering the energy system of both investors and host countries, we can detect some effects related to the higher installed capacity to produce renewable energy. If we consider renewable energy production as a proxy of the domestic efforts in new green technologies, ceteris paribus, we might expect leaders in renewable technologies to correspond to those countries with a higher propensity to invest in CDMs, in order to maximise benefits from domestic efforts in such new environmental technology domains thanks to the exploitation of competitive advantage in the international market.

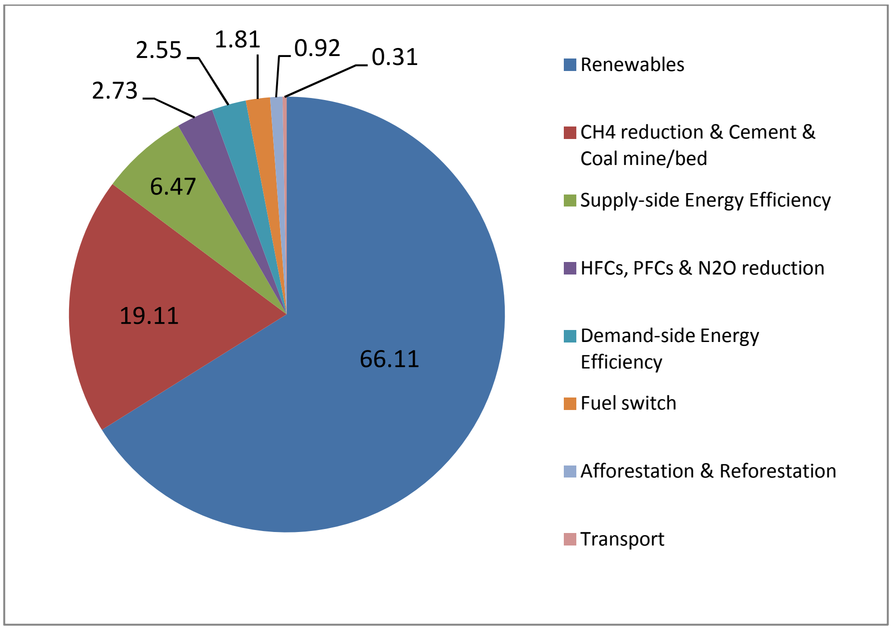
Secondly, this study also considers the specific influence played by the quality of the institutions both in investing and hosting countries in order to investigate which aspects of institutional quality influence CDM investments propensity the most.

### *2.2 The role of sustainable development*

The focus here will mainly be on the second policy objective of the CDM, namely sustainable development. The empirical analysis presented here will contribute to disentangling the factors that explain why the objective of stimulating sustainable development in poor economies is not one of the most important criteria used for choosing the destinations of a CDM project. Descriptive statistics of the distribution of CDM projects rely on official information provided by the United Nations Framework Convention on Climate Change (UNFCCC) and the CDM Pipeline from 2005 to 2011. These data give information on the number of projects implemented (by scope, host country and investor), as well as the amount of investments and issued CERs by a host country.

As of 31 December 2011, there were 3931 implemented projects. However, these are distributed unequally in terms of both project type and geography. Figure 1 shows the distribution of projects by type. It is worth noting that 66% of the implemented projects are in the renewables sector, and the percentages of other types of project are considerably lower.

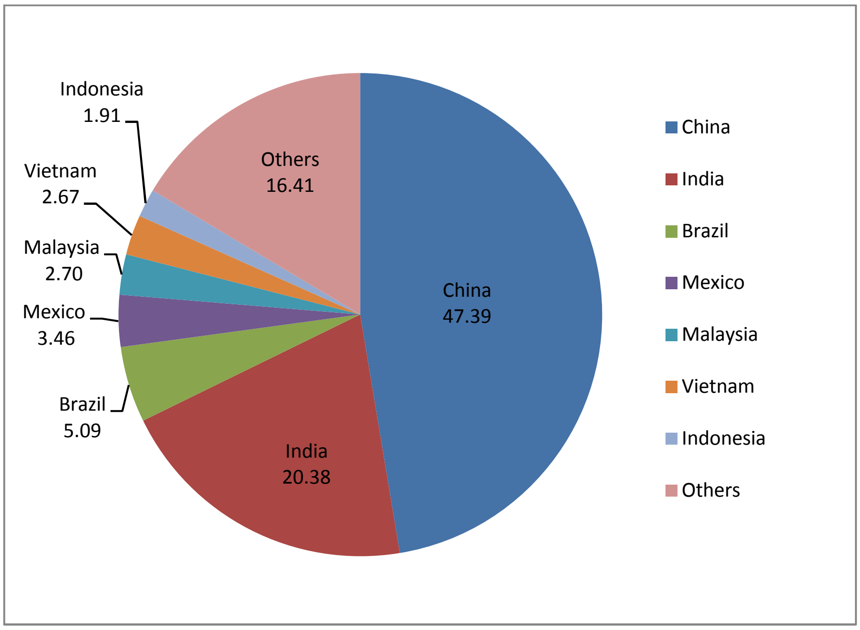
**Figure 1 – Project distribution by scope (% of total projects as of 31 December 2011)**




Source: Adapted from UNEP (2012)

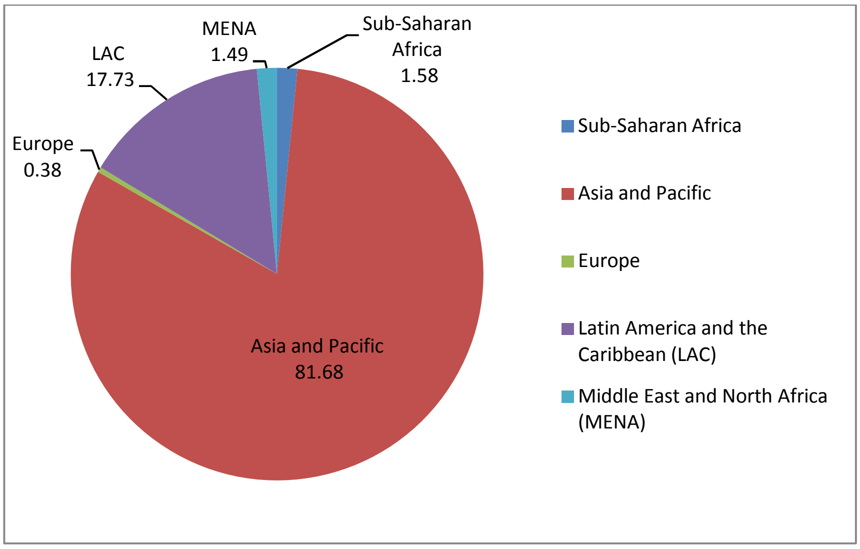
Regarding the geographical distribution of CDM projects, as of 31 December 2011 only 73 developing countries were host to a project (with many hosting just one; see Figure 2). China hosts almost half of the projects, while the LDCs host only 4.6% of them. Even worse, only 1.58% of CDM projects are in Sub-Saharan Africa, where most of the LDCs are located (Figure 3).

**Figure 2 – Project distribution by host party (% of total projects as of 31 December 2011)**




Source: Own elaboration on UNFCCC (2012)

**Figure 3 – Regional distribution (% of total projects as of 31 December 2011)**

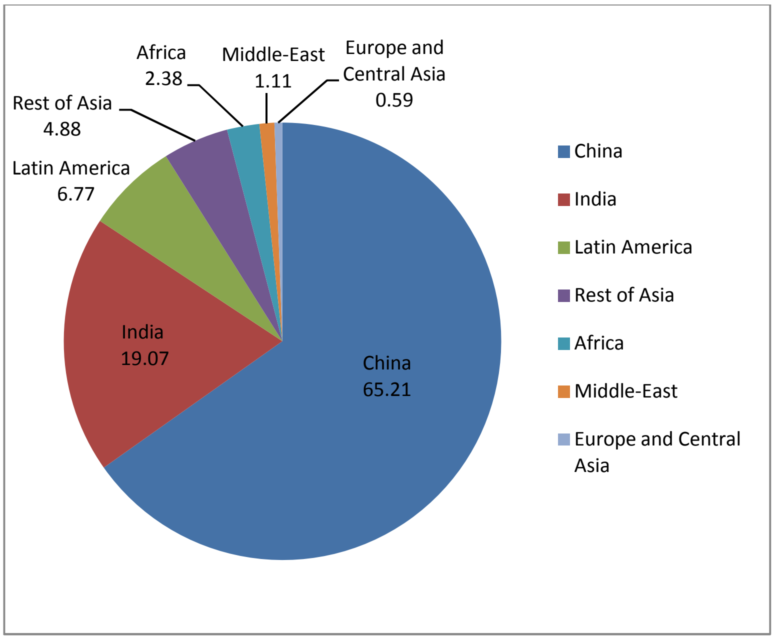



Source: Own elaboration on UNFCCC (2012).

As a matter of fact, this diagram shows that the CDM is far from achieving its dual purpose, becoming little more than a tool for cost reduction for developed countries, without contributing to the achievement of sustainable development in the poorest countries. In fact, even if sustainability criteria are satisfied for the granted projects, the goal of providing development opportunities to all host countries is a long way off..

The money invested in the CDM, which was around US$188 billion by 2011, was mainly invested in China (65%) (Figure 4).

**Figure 4 - Destination of CDM investments (% of total investments as of 31 December 2011)**

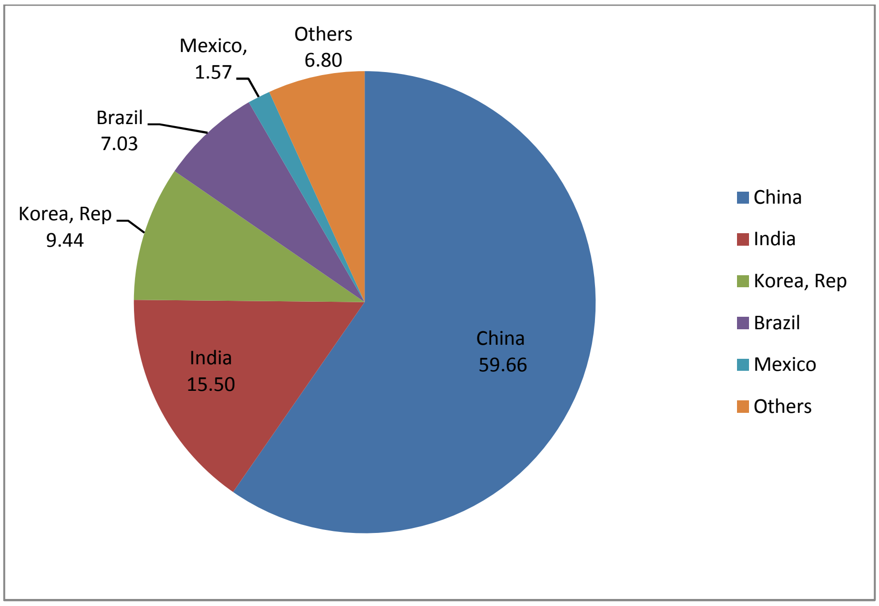



Source: own elaboration on UNEP (2012).

If we compare results in Figures 2 and 4, we can see that CDM investment flows in China have been even larger than the number of projects. This means that there is a great concentration of large size projects in China. Moreover, the number of CERs issued by the host party reflects the distribution of projects, as illustrated in Figure 5. If we compare Figures 2 and 5, it is also worth noting that the only difference is represented by the Republic of Korea. Even if it has hosted fewer projects than Brazil and Mexico, a larger amount of CERs have been issued (9.44% of total CERs) in this country. This evidence tells us that there is some heterogeneity in reduction costs and investment efficiency in implementing CDM projects in different countries.

The total number of CERs issued has been increasing over the years. It went from about 350 million up to 2009 to 496 million in 2010 and reached 877 million in 2011 (IGES, 2012; UNFCCC, 2009). As each CER is equivalent to one ton of CO2-eq, this means that so far about 877 Mt CO2-eq. have been abated through CDM projects. Finally, although CDM projects mostly follow the emission reduction objective and neglect the sustainable development one (Sutter and Parreño, 2007), the distribution of projects does not always respect a cost effectiveness criterion. For this reason, Table 1 shows the "Investment efficiency" (calculated as the ratio between the number of CERs and the relative amount of investments) for the first twenty host countries.[4]

**Figure 5 - CERs issued by host party (up to 31 December 2011)**




*Source: own elaboration on IGES (2012).*

A comparison of the host country ranking for CDM Investment and Investment Efficiency shows that host countries (corresponding to the top ranks) have not been those with the highest efficiency (with the exception of Brazil). The best example is China. It is first in the ranking of host countries both in terms of amount of investments (Ranking (1)) and in terms of issued CERs (Ranking (2)), but if we look at its position in the ranking in terms of efficiency (Ranking (3)), we can see that it loses five positions and is in sixth place. It can also be seen that India, ranked second for CDM Investment and CERs issued, but only eighth for Investment Efficiency, is in a similar position. Conversely, countries such as the Republic of Korea and Argentina, are quite highly ranked in terms of Investment Efficiency despite the fact that they do not attract much investment (they are, respectively, in first and third place in terms of efficiency, gaining six and fourteen positions with respect to the ranking in terms of amount of investments). This phenomenon can be partially explained by the presence of decreasing returns to scale of CDM projects due to concentration. However, these data suggest that there must be other factors that are influencing

[4] The best way to compare abatement investment efficiency should be to rely on marginal abatement cost (MAC) curves in the developing countries where CDMs are implemented. As a matter of fact, detailed MACs are available only for few countries, thus forcing us to consider the only suitable information as the average abatement cost here given by the inverse of the investment efficiency index.

the distribution of projects, which continue to be in emerging economies rather than more cost-effective developing countries.

If cost effectiveness is the leading factor driving investment decisions, when a large concentration in few selected host countries leads to decreasing returns to scale, or in other words, investment efficiency as described by Column (3) in Table 1 is lower, then one might expect CDM project concentration to decrease.

**Table 1 – Efficiency Indices**

| Host country | CDM Investment (Million US$) (1) | CERs (tons of $CO_2$) (2) | Investment efficiency (ton of $CO_2$ per mln US$) (3)=(2)/(1) | Ranking (1) | Ranking (2) | Ranking (3) |
|---|---|---|---|---|---|---|
| China | 122,587 | 522,980,763 | 4,266 | 1 | 1 | 6 |
| India | 35,844 | 135,888,099 | 3,791 | 2 | 2 | 8 |
| Mexico | 3,627 | 13,746,702 | 3,790 | 3 | 5 | 9 |
| Brazil | 2,616 | 61,661,852 | 23,574 | 4 | 4 | 2 |
| Indonesia | 2,236 | 3,515,680 | 1,572 | 5 | 10 | 14 |
| Vietnam | 2,093 | 6,743,234 | 3,222 | 6 | 9 | 10 |
| Korea, Rep. | 1,824 | 82,717,715 | 45,348 | 7 | 3 | 1 |
| Colombia | 1,575 | 1,655,795 | 1,051 | 8 | 13 | 17 |
| Nigeria | 1,190 | 312,364 | 262 | 9 | 19 | 19 |
| Peru | 1,136 | 1,688,437 | 1,486 | 10 | 12 | 15 |
| Chile | 1,067 | 8,530,588 | 7,995 | 11 | 7 | 5 |
| Malaysia | 889 | 2,133,604 | 2,399 | 12 | 11 | 11 |
| Egypt | 787 | 7,434,115 | 9,440 | 13 | 8 | 4 |
| Morocco | 766 | 330,099 | 431 | 14 | 18 | 18 |
| Israel | 738 | 1,226,454 | 1,663 | 15 | 15 | 13 |
| Thailand | 547 | 1,045,379 | 1,910 | 16 | 16 | 12 |
| Argentina | 427 | 8,896,259 | 20,839 | 17 | 6 | 3 |
| Philippines | 400 | 496,007 | 1,241 | 18 | 17 | 16 |
| United Arab Emirates | 382 | 91,746 | 240 | 19 | 20 | 20 |
| Ecuador | 335 | 1,279,792 | 3,822 | 20 | 14 | 7 |

*Source: own elaboration on IGES (2012) and UNEP (2012).*

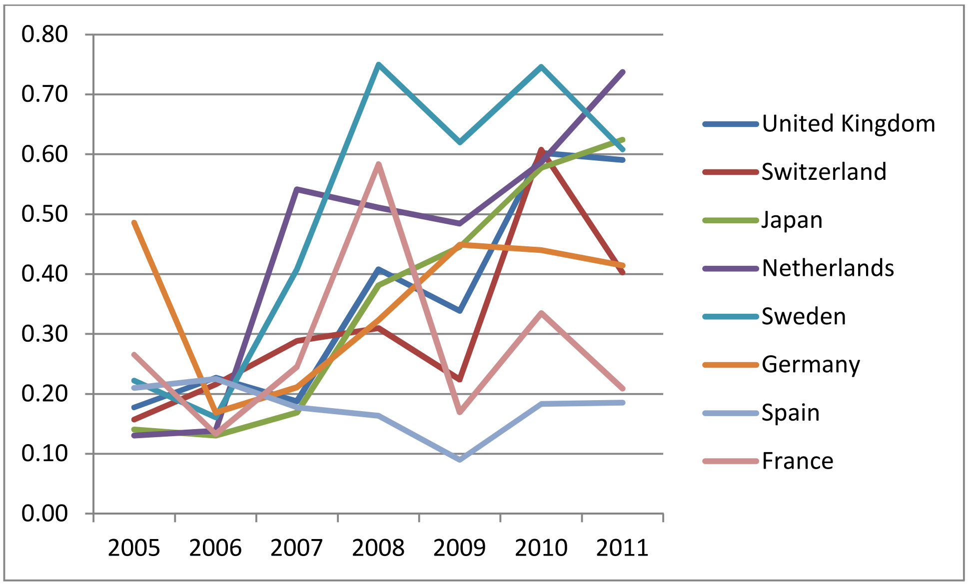
If one looks at the main investors, it can be seen that exactly the opposite has occurred, because the concentration of final destination has increased over time for almost all countries considered. The largest investors (namely the United Kingdom, Switzerland, Japan, the Netherlands, Sweden, Germany, Spain, France), representing about 90% of total CDM projects, were selected over the whole period 2005-

2011. A Herfindahl concentration index was computed for each investing country ($H_{it}$) in the form:

$$H_{it} = \sum_{j=1}^{N} \left( \frac{CMD_{ijt}}{\sum_{j=1}^{N} CMD_{ijt}} \right)^2 \qquad (1)$$

where *i* is the investor and $CDM_{ijt}$ is the number of CDM projects made by country *i* in each *j-th* host country for year *t*. The Herfindahl index ranges from 1/N to one, where N is the number of host countries. In order to compute a fully comparable index for the selected countries, this study considers the same host countries for all investors with a common N for all. Since as is common knowledge, values above 0.25 indicate a high concentration, it is quite clear from the trends shown in Figure 6 that the market was concentrated from the beginning of the analysed period as the Herfindahl index ranges from 0.15 to 0.50. More importantly, the concentration level has risen substantially for almost all large investors, with values ranging from 0.20 to 0.75.[5]

**Figure 6 – Trend in Herfindahl concentration index of CDM projects for destination countries (eight main investors, 2005-2011)**



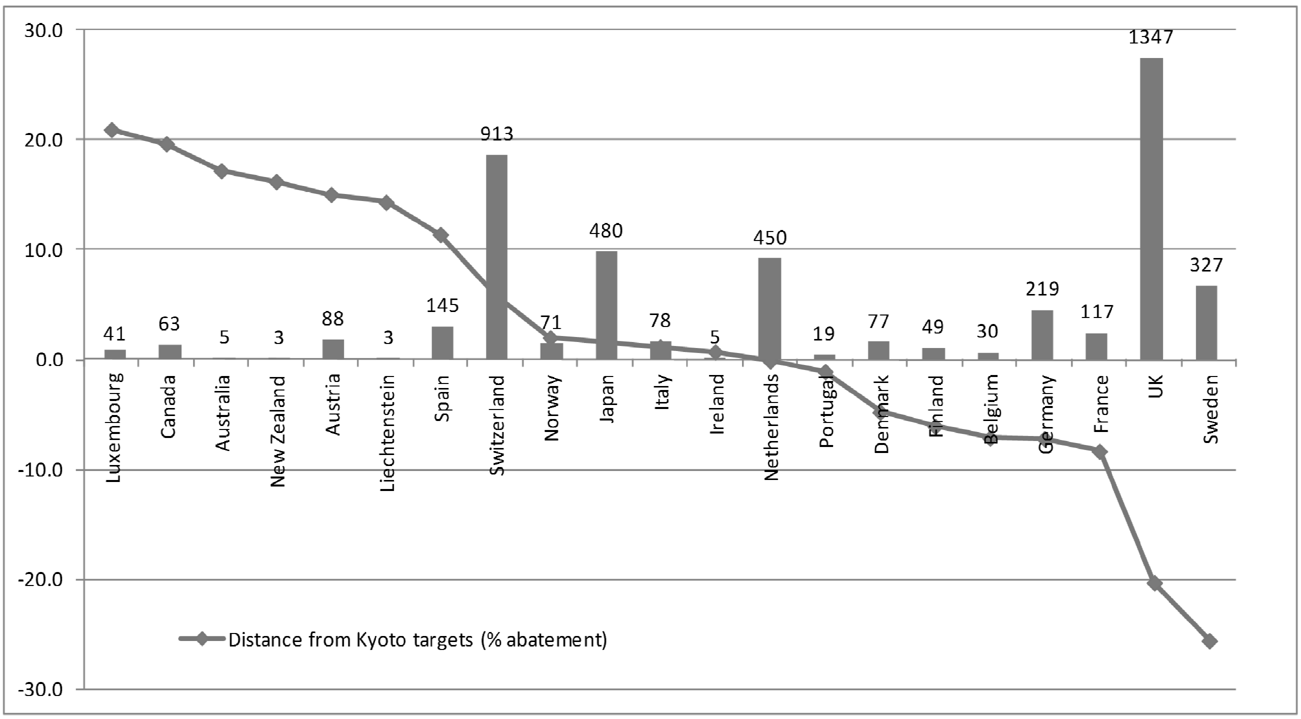

Source: own elaboration on UNFCCC (2012).

[5] By looking at distinguished host countries for the four top investors (namely the United Kingdom, Switzerland, Japan and the Netherlands), it is also worth noting that the largest concentration is given by increasing projects directed towards China, with a clear crowding out effect compared with projects directed towards all the other destinations (see Figure A1 in the Appendix).

By looking at Figure 7, United Kingdom is the country that has implemented most CDM projects, followed by Switzerland, with a very high number of projects compared with those implemented by other countries. Thus, there is quite a clear positive correlation between the number of projects implemented by investors and concentration degree for final destination. This phenomenon reveals a strong path dependency on investment decisions which is far from being fully explained by the sole cost effectiveness criterion. Since common economic bilateral relationships (e.g., trade flows or Foreign Direct Investment decisions) are often strongly affected by path dependency, this confirms the motivation for our principal research question.

Although not all Annex I countries are investing in CDM, the number of projects implemented has been increasing over the years. This reflects the fact that during this period, as previously argued, the role of CDM in mitigation actions has been growing. Nevertheless, the cost effectiveness objective as well as the environmental purpose (abatement targets compliance) do not seem to explain the implementation of CDM projects, as we can see by comparing the number of projects implemented by Annex I countries represented by figures on the top of grey bars, and their distance from Kyoto targets as represented by the grey line (Figure 7).

**Figure 7 - Comparison between the number of CDM projects implemented by Annex I countries and their distance from Kyoto targets in terms of percentage of abatement**




Source: Own elaboration on UNFCCC (2011, 2012).

This distance was calculated in terms of the percentage of abatement, using 2009 data, the most recent emissions data available. Positive numbers indicate a greater distance from Kyoto targets and vice versa, as measured by the left hand side y-axis.

At a general level, it should be noted that there is no univocally determined correlation between the distance from Kyoto targets and the number of projects implemented: countries that are far from their objectives are also those that have implemented fewer projects (e.g., Australia, Canada, Luxembourg) and vice versa (e.g., France, Germany, Sweden, the United Kingdom). For example, the United Kingdom is the country that has implemented the greatest number of projects, even though it has reached its Kyoto target, whereas countries such as Australia and New Zealand have implemented very few projects, although they are very far from achieving their obligations. A first but unsatisfactory explanation could be given by the possibility that a country that has reached its Kyoto target may decide to invest in CDM in order to obtain CERs that afterwards could be sold to other developed countries that still have not reached their objectives. Nonetheless, all these descriptive facts provide a quite complex framework where several factors are behind the geographical concentration of CDM investment flows. This reinforces the motivation for our research question that CDM are influenced by factors other than pure cost minimisation and/or sustainable development criteria.

## 3. Econometric strategy and dataset description

### *3.1 Gravity model for bilateral relationships*

Bilateral relationships among several countries in economic studies are often analysed by adopting an empirical model based on a gravity equation. Such a model is mostly used in trade analysis, but is also becoming widely used for other issues. One example is given by Picci (2010), where a gravity model is applied to patent data in order to investigate the degree of internationalisation of the inventive activity among European countries. Another example is specifically applied to CDM projects according to the modified gravity equation presented in Wang and Firestone (2010). This is the only example of gravity model applied to bilateral CDM relationships, where only a few elements are under scrutiny and further research is needed. According to a generalised gravity model of trade (Anderson, 1979; Bergstrand, 1985), the volume of trade between pairs of countries $Y_{ij}$ is a function of their incomes, populations, geographical distance, the existence of bilateral trade agreements or common languages, as follows:

$$Y_{ij} = X_i^{\beta_1} X_j^{\beta_2} P_i^{\beta_3} P_j^{\beta_4} F_i^{\beta_5} F_j^{\beta_6} Z_{ij}^{\beta_7} \exp(\alpha_{ij}) u_{ij} \quad (2)$$

where *i* stands for countries playing an active role in the investigated issue, called reporters in international economic terms, and *j* represents countries, also called partners.

In this specification, $X_i$ and $X_j$ indicate the role of economic size of trading partners, usually represented by the GDP of the reporter and the partner, $P_i$ and $P_j$ are reporter and partner populations whereas $F_i$ and $F_j$ represent all other specific reporter and partner features that may affect trade flows such as the quality of institutions, infrastructures and technological capabilities. $Z_{ij}$ represents any other factor aiding or preventing trade between each pair of countries with a specific country-pair dimension. The most important bilateral driver included in $Z_{ij}$ is represented by the geographical distance between the two countries, measured in several ways. Another bilateral factor is given by the existence of past colonial relationships, a common language or the existence of a bilateral trade agreement. The basic idea is that trade relations are influenced by the economic size of the trading partner where the income and population dimensions are proxies of demand and supply of the importer and the exporter whereas geographical distance generally represents a proxy for transport and other transaction costs. Finally, $\alpha_{ij}$ represents the specific effect associated with each bilateral trade flow as a control for all the omitted variables that are specific to each country-pair trade flow whereas $u_{ij}$ is the error term.

According to the modified gravity model applied to CDM bilateral transactions developed by Wang and Firestone (2010), the log linearisation of eq. (2) results as:

$$lnCDM_{ij} = \alpha_0 + \beta_1 lnD_{ij} + \beta_2 lnE_i + \beta_3 lnE_j + \beta_4 lnF_i + \beta_5 lnF_j + \beta_6 lnZ_{ij} + \varepsilon_{ij} \quad (3)$$

where the dependent variable $CDM_{ij}$ represents the CDM permits purchased from credit country i in host country *j*, $D_{ij}$ measures the geographical distance calculated by computing the great-circle distances between credit and host countries' capitals, $E_i$ and $E_j$ represent GHG emissions in investing and host countries and $F_i$ and $F_j$ represent other structural features related to investing and host countries such as, for instance, the infrastructure endowments or the education level. Finally, $Z_{ij}$ represents other bilateral features according to the trade model related to the existence of common language and past colonial relationships.

### *3.2 The econometric model and dataset*

According to the research hypothesis, the empirical model differs from Wang and Firestone (2010) in several ways. First of all, empirical estimations are based on a panel dataset where bilateral relationships are shaped over the period 2005-2011 when data on CDM projects are fully available from UNFCCC for each single year. This means that, unlike Wang and Firestone (2010), the dependent variable is not represented by 1st period $CO_2$-equivalent emissions reductions (CERs) expected to be generated by the projects available for the whole period, but is represented by the number of projects implemented each year by investing countries in host countries. This methodological choice allows us to investigate the investment patterns in a temporal dimension as well. An important issue related to this aspect is given by the potential changes over time in CDM locations. It could be that one Annex I country, after having implemented several CDM projects in selected countries, faces increasing marginal abatement costs (MAC), especially if several CDM projects, also coming from other Annex I countries, are concentrated in those selected countries. This means that some changes in investment destinations may occur and only annual data allow this specific aspect to be investigated.

Second, within the country-pair features, the role of already existing commercial relationships is explicitly modelled by investigating the role of bilateral trade as a consolidated channel of international exchange that also facilitates CDM investment decisions. Third, the role of institutional quality is included in order to account for the well-known constraint faced by investors in CDM projects, where the capacity of managing such projects in host countries, as well as the existence of emissions inventory systems or well-established rules for international transactions, may influence investment behaviour.

In order to account for path dependency in bilateral relationships, some independent variables are modelled with one time lag, in order to have a clearer picture of how existing (path-dependent) bilateral relationships influence CDM final destination decisions. In order to do this, while CDM projects are shaped in the whole period 2005-2011, all the other regressors are provided for the period 2000-2011 in order to maintain all available observations for CDM while allowing independent variables to be lagged appropriately. This modelling choice also allows us to reduce estimation biases deriving from potential endogeneity of some regressors. In particular, by strengthening bilateral relationships through CDM investments, one might expect a more favourable investment environment to be created that also facilitates bilateral commercial relationships. This specific point could constitute an interesting future research issue, but it is beyond the scope of this work.

The estimated empirical model is as follows:

$$lnCDM_{ij,t} = \alpha_{ij} + \gamma_{i,t} + \delta_{j,t} + \beta_1 lnD_{ij} + \beta_2 dLang_{ij} + \beta_3 ln\boldsymbol{M}_{i,t-p} + \beta_4 ln\boldsymbol{M}_{j,t-p} + \beta_5 lnT_{ij,t-p} + \beta_6 lnI_{i,t-p} + +\beta_7 lnI_{j,t-p} + \beta_8 lnN_{i,t-p} + \beta_9 lnN_{j,t-p} + \beta_{10} dEU_i + \varepsilon_{ijt} \quad (4)$$

where $p$ stands for the number of lags which are statistically robust. The criterion used to check for value of $p$ is to minimise the number of lags. As a result, the empirical estimations presented in Section 4 are all derived by a temporal lag structure with $p$=1.

In this specification, the variable ($lnD_{ij}$) represents the geographical distance between each pair of countries and is calculated as the great-circle formula taking distances from capitals and ($dLang_{ij}$) is a dummy variable representing the existence of a common language for each country pair (Mayer and Zignago, 2006). According to a gravity-based trade theory, one might expect $\beta_1$ to be negative and $\beta_2$ to be positive since distances are commonly considered as a proxy of transport costs curbing transactions whereas the existence or not of a common language may facilitate international exchanges.[6] Several remarks are in order. First, a set of explanatory variables representing the role of mass for i and j countries ($ln\boldsymbol{M}_{i,t-p}$ and $ln\boldsymbol{M}_{j,t-p}$) is introduced here. Several measures of mass were tested because there are, as yet, no decisive empirical findings on this issue. One measure of mass is the economic size of reporters and partners modelled by using gross domestic product (GDP) per capita at purchasing power parity (PPP), available from the World Development Indicators (WDI) online database (World Bank, 2012).[7] Second, as already stated, the number of projects and the investment dimension are strongly influenced by MACs. Here this issue is shaped by including country specific $CO_2$ emissions level for *i* and *j* countries, as the sum of all GHG emissions expressed in $CO_2$ equivalent terms provided by WDI. It is clear

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[6] The role of past colonial relationships is also controlled, but it is not a robust regressor.

[7] A complete description of all variables with acronyms, sources and main statistics is available in the Appendix, Tables A1 and A2.

that in this empirical framework, both $\beta_3$ and $\beta_4$ are expected to assume positive values. With regard to the reporter's emissions level, the higher the total emissions flow for each year, the harder the abatement efforts for respecting emission targets. This means that the propensity to invest in CDM projects for the purpose of reducing MACs should be higher. With regard to the host countries, the higher the level of total $CO_2$ emissions, the wider the range of available abatement possibilities (i.e. the lower the MAC). Third, in order to gather information on the role of the energy system, the role of electricity production as well as the level of electricity produced by renewable sources was controlled for. Recalling the main findings of the trade-based gravity model, mass plays a role as a demand driver. This means that in both cases - by using GDP per capita or total electricity production - $\beta_3$ and $\beta_4$ were expected to assume a positive sign. The larger the economic or energy system, ce*teris paribus*, the higher the demand for a wide range of abatement tools in order to be compliant with emission targets. With regard to electricity production by renewable sources, a theoretically based sign is only valid for the investing country. Bearing in mind that CERs may be banked and then sold into the carbon market, the gravity equation has been modelled in order to reply to the ancillary research question related to the hypothesis that the higher the domestic installed capacity of renewable electricity, the higher the potential to exploit such technologies by investing abroad. It may be that countries that are highly specialised in renewables coincide with the countries facing reduced constraints in terms of distance from achieving emission targets. Nonetheless, a large endowment of renewable energy sources also reveals a strong capacity to implement similar power plants abroad. As a matter of fact, even if one country is already compliant with emission targets thanks to its efforts to develop renewables domestically, it might find it convenient to invest in CDM projects that exploit renewable technologies in order to gain from accumulating CERs and selling them into the carbon market.

To answer the main research question, the role of bilateral trade relationships ($\ln T_{ij,t-p}$) was tested, here modelled as bilateral export flows expressed in PPP terms from each investing country towards each host country with one temporal lag. To reduce potential variability in trade data dependent on pure computational issues, as a common choice in the trade literature for bilateral relationships, a two-year moving average value was computed. This means that for each country-pair the export value included in the analysis results as the average between the current value and that taken from the previous year.

In addition, because there have been several concerns in recent years regarding severe constraints given by a weak institutional setting of host countries, the quality of institutions of both investing and host countries was scrutinized, thus investigating the second ancillary research question. A weak institutional framework is widely recognised as a source of uncertainty for investment decisions in all economic issues (Rodrik *et al.,* 2004). In CDM projects, the absence of a statistical office for the certification of emissions reductions in host countries, since in Non-Annex I countries emissions registry is not compulsory, and the low quality of rules for respecting legal aspects of contracts and agreements, have both been recognised as important concerns regarding when investment decisions should be taken. As a matter of fact, all CDM projects are complemented by a Memorandum of Understanding (MOU) where parties compile a formal statement in order to make sure that rules for certificating emission reductions and the commitment of investors to ensure sustainable development activities are respected. In a gravity model, both sides of each country-pair are included where the robustness of $\beta_7$ with a positive sign is a clear indication of the role played by institutional quality in acting as an attractor of investment decisions. On the contrary, no clear expectations at theoretical level should be given to the role of institutional quality in investing countries. On the one hand, countries with a higher level of institutional stability may be those with a stronger capacity to invest abroad since a domestic high institutional profile ensures a good overall investment environment for firms which are more robust and consequently more competitive on international markets. On the other, weak institutions may coincide with a scarce capacity to induce private firms to be compliant with domestic emissions reduction, thus increasing the necessity to invest in CDM in order to achieve a sufficient number of CERs required for fulfilling abatement targets.

Data for shaping institutional quality for $i$ ($lnI_{i,t-p}$) and $j$ ($lnI_{j,t-p}$) countries are taken from the Political Risk Services Index (PRI) provided by the PRS Group since it provides a homogeneous set of indices measuring various dimensions of political and socio-economic conditions for a large number of countries and a long time span. Within the 12 single indices provided by PRI, Law and Order (LO) and Investment Profile (IP) were selected. Law and Order is one of one of the most widely used institutional quality indices, and IP is the measurement most closely related to the object of the present analysis. As the maximum values of the two indices provided by the PRS Group are different (6 for LO and 12 for IP), in order to conduct the analysis, these values were normalized to a common scale with 12 as the maximum value.

Finally, controls for two specific issues were included. The first consists in controlling for the role of electricity production from nuclear power plants for i $(lnN_{i,t-p)})$ and j$(lnN_{j,t-p)})$. As a matter of fact, when countries specialise in nuclear production, in order to comply with reduction targets, the most cost-effective way of reducing GHG emissions is to intensify nuclear energy production, which indirectly reduces the propensity to invest in CDM projects. It was expected that, for countries i and j, both $\beta_8$ and $\beta_9$ would be negative, with a greater emphasis on investing countries. The second issue relates to the level of involvement in international climate change negotiations. According to the role played by different countries in COPs, it might be expected that European Union (EU) countries would show the largest propensity to invest in CDM projects in the analysed period because they form the bargaining bloc that is pushing for a post-Kyoto agreement with rather challenging abatement efforts. As a matter of fact, from the description provided in Section 2, clear EU predominant behaviour emerges in CDM distribution whereas some countries included in the so-called Umbrella Group (e.g., Australia and New Zealand) are lagging behind. Hence, it might be expected that these countries would both show a relative higher propensity to invest in CDM in order to reduce abatement costs and be first comers in this new market. For this reason, a dummy variable $(dEU_i)$ was included, with a value of 1 assigned if the investing country was an EU member, and 0 otherwise.

Investing countries $i$ are all countries included in Annex I list $(\forall i \in (1, M), with\ M = 20)$ which have invested in one CDM project at least over the period 2005-2011 (i.e., Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom), while the host countries j $(\forall j \in (1, N), with\ N = 126)$ are all the potentially receiving countries as specified on the UNFCCC website, during the same period.[8] The total number of potential observations in a panel setting is thus given by

[8] The complete list of host countries is: Albania, Algeria, Angola, Antigua and Barbuda, Argentina, Armenia, Azerbaijan, The Bahamas, Bahrain, Bangladesh, Barbados, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Chad, Chile, China, Colombia, Comoros, Congo Dem. Rep., Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Djibouti, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Ethiopia (excludes Eritrea), Fiji, Gabon, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Iran Islamic Rep., Israel, Jamaica, Jordan, Kenya, Korea Dem. Rep., Korea Rep, Kuwait, Kyrgyz Republic, Lao PDR, Lebanon, Lesotho, Liberia, Libya,

$Obs. = M\text{x}N\text{x}T = 17{,}640.$

As a matter of fact, since a panel estimation is carried out, in order to receive robust results, the dataset should be balanced, meaning that we need to set the same set of years and host countries for each investor even if there was no CDM project in that specific year or country. This leads to a dataset that is fully coherent with a theoretically-based gravity model (Anderson and van Wincoop, 2003) where the absence of a bilateral flow is also an input to be accounted for. In such a dataset, the presence of many zeros as well as the characteristic of being a discrete dependent variable may lead to statistical problems. Recent advancements in the econometric estimation of a gravity model provide useful suggestions in this regard. According to Santos-Silva and Tenreyro (2006), in order to solve potential sample selection problems, a maximum-likelihood (ML) estimator performs better than an OLS estimator. Conversely, following Helpman *et al.* (2008), a large part of the statistical bias produced by the existence of many zeros is not due to a sample selection problem but rather to neglecting the impact of firm heterogeneity in the decision on how much volume to export and the choice of the final destination market. In particular, a Heckman's two-stage procedure is used to account for selection and heterogeneity biases in the case where some explanatory variables - related to the costs of establishing trade flows which affect firms' decisions to export or not - are only included in the first stage equation (Wooldridge, 2010). This procedure is valid for continuous dependent variables and is theoretically derived specifically for trade data. In the present case, the discrete nature of the dependent variable allows us to rely on ML estimators rather than on a two-stage procedure. It is also worth mentioning that Helpman *et al.* (2008) specifically focused on the decision to trade by single firms whereas the framework of this analysis is rather different from a pure trade model. Since no information is available on the dimension of each single project (e.g., bilateral annual investments), ML is the best available option. In addition, our dependent variable has many zeros with large overdispersion. Econometric models specifically designed for this kind of variable are the Poisson Regression Model (PRM) and the Negative Binomial Regression Model (NBRM). Broadly

Macedonia FYR, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Qatar, Rwanda, Samoa, Saudi Arabia, Senegal, Sierra Leone, Singapore, Solomon Islands, South Africa, Sri Lanka, St. Lucia, Sudan, Suriname, Swaziland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkmenistan, Uganda, United Arab Emirates, Uruguay, Uzbekistan, Vietnam, Yemen, Zambia, Zimbabwe. It is worth mentioning that Montenegro and Serbia are excluded since all available data are provided for the two countries as an aggregate, and only Serbia shows one single CDM project over the whole period.

speaking, the PRM assumes that the dependent variable has a Poisson distribution, denoted by $y \sim Poisson(\mu)$, where $\mu$ is the intensity parameter and the conditional mean is estimated from observed characteristics. In this way, the model extends the Poisson distribution by allowing each observation to have a different mean, referred to as incorporating observed heterogeneity. However, while the PRM is the natural starting point for the analysis of count data, it might be biased by an excess in zeros and an overdispersion problem. If the equidispersion assumption of the Poisson model, given by the equality of the conditional mean and the conditional variance, is violated, the model under-estimates the probability of a zero count and in general of low counts (Cameron and Trivedi, 1986).[9]

The additional dispersion can be accounted for in many ways. The NBRM addresses the failure of the PRM by introducing unobserved heterogeneity across the Poisson means. In the PRM model, the observation units are still Poisson distributed but there is a random variable, e.g. $\nu$, that generates additional variability in the outcome, so that $y \sim Poisson(\mu\nu)$. Given that our dependent variable is strongly overdispersed, a NBRM model is used to estimate eq. (4).[10] The maximum likelihood method is used to estimate the model parameters.[11]

Finally, in order to account for unobservable country-pair specific heterogeneity ($\alpha_{ij}$), a fixed effects estimator was adopted by conditioning the probability of the counts for each group on the sum of the counts for the group.[12] According to recent findings in gravity model estimations for a panel dataset, time variant fixed effects for reporters and partners should also be included (Baldwin and Taglioni, 2006).

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[9] Alternative methods are used for variables with excessive zeros (zero-inflated negative binomial regression, Hurdle models, etc.). See Cameron and Trivedi (2009) for a more comprehensive discussion.

[10] Mean and variance for the dependent variable are 0.15 and 7.96 respectively. The Likelihood-ratio test on the overdispersion parameter is 4,511.5 with p-value 0.00, thus providing strong evidence of the overdispersion. Consequently, the NBRM is preferred to the PRM. See the Appendix for descriptive statistics of the dependent variable, and graphical representations of the observed and predicted probability assuming a Poisson and a negative binomial univariate distribution for the dependent variable (Figure A2).

[11] The maximum likelihood negative binomial mean-dispersion estimator is not consistent if the variance specification is incorrect. As an alternative estimation strategy the basic equation has been estimated with the PRM using the pseudo maximum likelihood approach. This approach only requires that the conditional mean function is correctly specified and allows consistent estimation of the coefficients also if the count variable is not Poisson distributed (Wooldridge, 1999). As a further robustness check, models have also been estimated with the generalised method of moments (GMM). The GMM estimator is of special interest when the model includes variables not strictly exogenous. In both cases results do not change substantially. Thus, in the following we just report those based on the NBRM, which in the absence of significant changes in the estimated coefficients remains the most efficient estimation method..

[12] The Hausman test points out that the fixed effects estimator is more appropriate than the random effects estimator. As a mere example, the Hausman test computed for model (3) in Table 2 assumes value 269.00 (with p-value 0.00), thus rejecting the null hypothesis that difference in coefficients is not systematic.

Hence, time-variant country effects for *i* and *j* were included, as expressed by $\gamma_{i,t}$ and $\delta_{j,t}$.[13]

## 4. Empirical results

In order to answer the research questions, the analysis is divided into two stages. In the first stage, we investigate the role played by the variables representing the economic and energy structure as drivers of the implementation of CDM projects. In the second stage, regressors representing the role of commercial bilateral relationships and the quality of institutions are introduced into the econometric model.

The results of the first part of the analysis are shown in Table 2. After analysing the role of GDP per capita and $CO_2$ emissions separately (M1 and M2, respectively), additional estimations have been considered in which the economic aspect is analysed together with three alternative environmental variables: $CO_2$-eq emissions, electricity production and electricity production from renewable sources (M3, M4 and M5, respectively). It is worth noting that all coefficients for these variables are positive and statistically robust for both investors and hosting countries. In particular, the effect associated with $CO_2$ emissions reflects the results of previous studies, according to which the overall level of emissions can be considered a key driver for directing investments in CDM projects.[14] According to the general empirical setting described in eq. (4), several lag structures have been tested in order to reduce potential endogeneity while obtaining robust results. The optimal lag structure appears to be $p = 1$, but the results remain quite robust and stable for lag values higher than 1.

An interesting point concerns the role played by renewable energies. As expected, the higher the installed capacity of renewable energy production, the higher the probability that one *i-th* Annex I country will be a large investor in CDM. Equally, the larger the renewables in host countries, the higher the propensity to absorb CDM projects.[15]

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[13] It is worth mentioning that the original formulation of a NBRM model is given by an exponential function, while statistical packages often automatically transform the equation in a log linear form, as exactly represented by eq. (4). In that case, coefficients for log transformed regressors are interpreted as elasticties, while coefficients related to variables in level (in this case all dummy variables) represent semi-elasticities.

[14] Wang and Firestone (2010); Winkelman and Moore (2011).

[15] Since potential multicollinearity bias may arise from considering economic and energy variables simultaneously, correlation values between GDP per capita and alternatively CO2 emissions and all other energy-related variables are investigated. All correlation values are below 0.30. As a further robustness check, multicollinearity bias is also checked by computing Variance Inflation Factor (VIF) values for all covariates included in M3-M5 as well as condition numbers for the whole regressions. Values obtained for VIF for single variables are always below 5.00 and

**Table 2 – Testing for gravity model fitness to CDM investment decisions**

| Variable | M1 | M2 | M3 | M4 | M5 |
|---|---|---|---|---|---|
| Distance $_{ij}$ | -0.28 | 0.35* | -0.17 | -0.39 | -0.48* |
| | (-1.11) | (1.86) | (-0.56) | (-1.52) | (-1.76) |
| Language $_{ij}$ | 0.96*** | 0.3 | 2.18*** | 1.43*** | 1.18*** |
| | (2.67) | (0.93) | (4.95) | (3.69) | (2.77) |
| GDP per capita $_{i\,(t-1)}$ | 2.59*** | | 7.16*** | 4.42*** | 3.53*** |
| | (6.69) | | (9.95) | (8.09) | (6.1) |
| GDP per capita $_{j\,(t-1)}$ | 0.95*** | | 1.24*** | 1.27*** | 1.13*** |
| | (8.62) | | (7.8) | (9.25) | (8.61) |
| CO2 emissions $_{i\,(t-1)}$ | | 0.09 | 0.69*** | | |
| | | (1.08) | (5.65) | | |
| CO2 emissions $_{j\,(t-1)}$ | | 0.11** | 0.26*** | | |
| | | (2.08) | (3.45) | | |
| Electricity production $_{i\,(t-1)}$ | | | | 0.64*** | |
| | | | | (5.22) | |
| Electricity production $_{j\,(t-1)}$ | | | | 0.50*** | |
| | | | | (6.2) | |
| Electricity production (renewable) $_{i\,(t-1)}$ | | | | | 0.61*** |
| | | | | | (5.46) |
| Electricity production (renewable) $_{j\,(t-1)}$ | | | | | 0.20*** |
| | | | | | (3.68) |
| Nuclear energy consumption $_{i\,(t-1)}$ | -0.06 | -0.03 | -0.15* | -0.23*** | -0.27** |
| | (-1.04) | (-0.58) | (-1.76) | (-2.96) | (-2.47) |
| Nuclear energy consumption $_{j\,(t-1)}$ | 0.04 | 0.13 | -0.19 | -0.39*** | -0.11 |
| | (0.42) | (1.54) | (-1.52) | (-3.34) | (-1.15) |
| dEU $_i$ | 0.67** | -0.15 | 3.55*** | 2.51*** | 1.97*** |
| | (2.22) | (-0.48) | (6.67) | (5.68) | (4.61) |
| N | 5,019 | 3,330 | 3,330 | 3,880 | 3,839 |
| ll | -2,357 | -1,607 | -1,489 | -1,823 | -1,825 |
| $\chi^2$ | 313 | 253 | 368 | 387 | 374 |

***, **, * Statistically significant at the 1, 5 and 10% level. Standard errors in parentheses.

Moreover, the two control variables (nuclear energy consumption and the EU dummy) are both significant in the last three regressions. With regard to the role of nuclear energy consumption, it is worth noting that the negative sign, as well as the fact that this variable is only robust for investing countries, reflects expectations and confirms the hypothesis that abating GHG emissions through nuclear production reduces the need to invest in CDM. With respect to the poor statistical robustness of host countries, in this case it is mainly explained by the fact that only very few *j* countries have nuclear production and consumption.

mean VIFs for the whole regressions are always below 2. For condition numbers, the condition of statistics below 50.00 is always respected.

Further explanatory variables need to be introduced in a second set of econometric specifications (Table 3), representing the core of this study. In particular, the last three regressions of Table 2 are enriched by first investigating the role played by bilateral export flows (M1-M3) and then checking for the role of institutional quality (M4-M6), here shaped by Law & Order (LO).

**Table 3 – The role of bilateral commercial relationships and institutional quality**

| Variable | M1 | M2 | M3 | M4 | M5 | M6 |
|---|---|---|---|---|---|---|
| Distance $_{ij}$ | 0.16 | -0.11 | 0.08 | 0.46 | -0.04 | 0.15 |
| | (0.53) | (-0.4) | (0.3) | (1.33) | (-0.13) | (0.52) |
| Language $_{ij}$ | 1.70*** | 1.11*** | 0.94** | 1.78*** | 1.19*** | 1.03** |
| | (3.77) | (2.8) | (2.36) | (3.82) | (2.93) | (2.51) |
| GDP per capita $_{i\ (t-1)}$ | 6.34*** | 3.95*** | 3.32*** | 6.89*** | 4.21*** | 3.54*** |
| | (8.73) | (7.35) | (7.05) | (8.6) | (7.45) | (6.9) |
| GDP per capita $_{j\ (t-1)}$ | 0.89*** | 1.01*** | 0.85*** | 0.92*** | 1.13*** | 0.96*** |
| | (4.91) | (6.59) | (6.44) | (4.64) | (6.64) | (6.44) |
| CO2 emissions $_{i\ (t-1)}$ | 0.46*** | | | 0.51*** | | |
| | (3.32) | | | (3.48) | | |
| CO2 emissions $_{j\ (t-1)}$ | -0.07 | | | -0.11 | | |
| | (-0.55) | | | (-0.84) | | |
| Electricity production $_{i\ (t-1)}$ | | 0.41*** | | | 0.48*** | |
| | | (2.97) | | | (3.24) | |
| Electricity production $_{j\ (t-1)}$ | | 0.18 | | | 0.25* | |
| | | (1.45) | | | (1.76) | |
| Electricity production (renewable) $_{i\ (t-1)}$ | | | 0.48*** | | | 0.52*** |
| | | | (5.05) | | | (4.96) |
| Electricity production (renewable) $_{j\ (t-1)}$ | | | -0.01 | | | 0.02 |
| | | | (-0.14) | | | (0.35) |
| Nuclear energy consumption $_{i\ (t-1)}$ | -0.19** | -0.24*** | -0.30*** | -0.21** | -0.27*** | -0.32*** |
| | (-2.37) | (-3.35) | (-3.76) | (-2.52) | (-3.39) | (-3.53) |
| Nuclear energy consumption $_{j\ (t-1)}$ | -0.11 | -0.29** | -0.21** | -0.06 | -0.31** | -0.22** |
| | (-0.88) | (-2.45) | (-2.12) | (-0.46) | (-2.43) | (-2.06) |
| Export flows $_{ij\ (t-1)}$ | 0.37*** | 0.31*** | 0.45*** | 0.32*** | 0.23** | 0.41*** |
| | (3.49) | (3.21) | (6.91) | (2.74) | (2.16) | (5.8) |
| Law & Order $_{i\ (t-1)}$ | | | | -1.31 | -1.30 | -0.14 |
| | | | | (-1.54) | (-1.63) | (-0.18) |
| Law & Order $_{j\ (t-1)}$ | | | | 0.67*** | 0.46** | 0.53** |
| | | | | (2.62) | (2.03) | (2.33) |
| dEU $_{i}$ | 3.24*** | 2.34*** | 2.29*** | 3.33*** | 2.43*** | 2.35*** |
| | (6.13) | (5.38) | (6.09) | (6.02) | (5.43) | (5.84) |
| N | 3,330 | 3,880 | 3,839 | 3,114 | 3,660 | 3,625 |
| ll | -1,483 | -1,818 | -1,800 | -1,423 | -1,756 | -1,739 |
| $\chi^2$ | 384 | 399 | 407 | 378 | 395 | 399 |

***, **, * Statistically significant at the 1, 5 and 10% level. Standard errors in parentheses.

The first and most important result is that the coefficients for bilateral export flows are always positive and statistically significant. Moreover, the introduction of trade into the analysis makes the other variables significant for developed countries only, unlike that shown in Table 2 and reported in previous studies.[16]This confirms the hypothesis that cost effectiveness in abatement efforts is not the driving force influencing the decision on destination markets, but other criteria based on private benefits seem to prevail. In particular, the existence of bilateral trade relationships plays a large role in influencing the distribution of CDM projects.

This is also true in the second group of regressions when the institutional variable is introduced. With this regard, it is worth noting that LO is positive and significant for host countries. This is a clear sign of the role played by institutional quality in acting as an attractor of investment decisions: the presence of good quality institutions, in fact, means lower transaction costs as well as a lower risk for developed countries of seeing their investments fail. On the contrary, this aspect seems to be less important in influencing choices in the investing countries. When we introduce institutional quality, as represented by LO (models M4-M6), it is worth mentioning that coefficients associated with bilateral exports are slightly lower than when institutions are absent (models M1-M3). This reveals the need to account for all ancillary conditions, as previously stated in this paper, where institutional capabilities in host countries allow reduced investment risk and successful abatement actions.

It is also worth noting that, even in this case, the dummy variable for investing countries located in the EU($dEU_i$) is positive and significant, whereas the control variable for nuclear energy consumption is negative and significant for Annex I countries in all specifications and less robust for Non-Annex I parties.

Finally, a third set of econometric specifications is built in order to control for robustness (Table 4). As in the previous step, the analysis is carried out by revising the last three regressions of Table 2 (with GDP per capita and the three environmental variables). In this case, the first step consists of adding only the institutional variable LO, without considering trade (M1-M3) as a first robustness check for the role played specifically by institutions. By comparing the results in Table 3 (M4-M6) with those in Table 4 (M1-M3), coefficients for LO seem to be quite robust and consistent with previous findings.

[16] Wang and Firestone (2010); Winkelman and Moore (2011).

**Table 4 – Robustness check for alternative institutional quality measures**

| Variable | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 |
|---|---|---|---|---|---|---|---|---|---|
| Distance $_{ij}$ | 0.18 | -0.22 | -0.44 | -0.18 | -0.42* | -0.44 | 0.11 | -0.18 | -0.06 |
| | (0.53) | (-0.83) | (-1.41) | (-0.64) | (-1.66) | (-1.58) | (0.37) | (-0.68) | (-0.2) |
| Language $_{ij}$ | 2.20*** | 1.42*** | 1.74*** | 1.33*** | 1.07*** | 0.91** | 1.01** | 0.80** | 0.73* |
| | (4.84) | (3.6) | (3.87) | (3.16) | (2.81) | (2.2) | (2.36) | (2.06) | (1.84) |
| GDP per capita $_{i\ (t-1)}$ | 7.69*** | 4.63*** | 5.80*** | 5.15*** | 3.51*** | 3.07*** | 4.57*** | 3.13*** | 2.85*** |
| | (9.76) | (8.26) | (9.28) | (7.95) | (7.11) | (5.88) | (6.97) | (6.37) | (6.25) |
| GDP per capita $_{j\ (t-1)}$ | 1.22*** | 1.32*** | 1.39*** | 0.74*** | 1.07*** | 0.95*** | 0.48*** | 0.86*** | 0.78*** |
| | (7.03) | (8.72) | (8.31) | (4.96) | (7.73) | (6.96) | (2.79) | (5.46) | (5.59) |
| CO2 emissions $_{i\ (t-1)}$ | 0.70*** | | | 0.38*** | | | 0.18 | | |
| | (5.49) | | | (3.2) | | | (1.28) | | |
| CO2 emissions $_{j\ (t-1)}$ | 0.17* | | | 0.16** | | | -0.12 | | |
| | (1.93) | | | (2.13) | | | (-1) | | |
| Electricity production $_{i\ (t-1)}$ | | 0.65*** | | | 0.48*** | | | 0.26* | |
| | | (5.17) | | | (4.03) | | | (1.89) | |
| Electricity production $_{j\ (t-1)}$ | | 0.49*** | | | 0.43*** | | | 0.14 | |
| | | (5.43) | | | (5.39) | | | (1.06) | |
| Electricity production (renewable) $_{i\ (t-1)}$ | | | 1.03*** | | | 0.70*** | | | 0.56*** |
| | | | (7.21) | | | (6.09) | | | (5.48) |
| Electricity production (renewable) $_{j\ (t-1)}$ | | | 0.17*** | | | 0.19*** | | | 0.03 |
| | | | (2.86) | | | (3.34) | | | (0.39) |
| Nuclear energy consumption$_{i\ (t-1)}$ | -0.19** | -0.27*** | -0.91*** | -0.09 | -0.16** | -0.26** | -0.15** | -0.18*** | -0.27*** |
| | (-2.11) | (-3.21) | (-5) | (-1.23) | (-2.25) | (-2.52) | (-2.03) | (-2.73) | (-3.33) |
| Nuclear energy consumption$_{j\ (t-1)}$ | -0.14 | -0.39*** | -0.22* | -0.02 | -0.30*** | -0.1 | 0.04 | -0.22* | -0.17 |
| | (-1) | (-3.09) | (-1.8) | (-0.13) | (-2.65) | (-1.01) | (0.31) | (-1.87) | (-1.64) |
| Trade $_{ij\ (t-1)}$ | | | | | | | 0.32*** | 0.29*** | 0.35*** |
| | | | | | | | (2.87) | (2.78) | (4.92) |
| Law & Order $_{i\ (t-1)}$ | -1.74** | -1.62** | -0.46 | | | | | | |
| | (-2.05) | (-2.06) | (-0.49) | | | | | | |
| Law & Order $_{j\ (t-1)}$ | 0.64** | 0.48** | 0.99*** | | | | | | |
| | (2.48) | (2.07) | (3.96) | | | | | | |
| Investment Profile $_{i\ (t-1)}$ | | | | 22.56*** | 6.96*** | 8.68*** | 22.55*** | 7.14*** | 8.01*** |
| | | | | (7.68) | (6.08) | (7.05) | (7.7) | (6.15) | (6.66) |
| Investment Profile $_{j\ (t-1)}$ | | | | 0.80* | 0.68* | 0.83** | 0.77* | 0.67* | 0.66* |
| | | | | (1.91) | (1.93) | (2.26) | (1.86) | (1.91) | (1.82) |
| dEU $_{i}$ | 3.59*** | 2.55*** | 3.65*** | 1.55*** | 1.66*** | 1.64*** | 1.38*** | 1.57*** | 1.87*** |
| | (6.42) | (5.64) | (6.61) | (3.08) | (3.93) | (3.89) | (2.78) | (3.77) | (4.92) |
| N | 3,114 | 3,660 | 3,625 | 3,114 | 3,660 | 3,625 | 3,114 | 3,660 | 3,625 |
| ll | -1,427 | -1,758 | -1,753 | -1,358 | -1,726 | -1,710 | -1,354 | -1,722 | -1,698 |
| $\chi^2$ | 369 | 389 | 413 | 345 | 400 | 379 | 350 | 403 | 406 |

***, **, * Statistically significant at the 1, 5 and 10% level. Standard errors in parentheses.

The variable LO is then replaced with another institutional variable, closely related to the investment environment, as represented by Investment Profile (IP) (M4-M6). By looking at the first set of results, it is worth noting that, although LO seems to play a relevant role in representing the host country features, this second institutional variable (IP) is more robust for investing countries. This seems to confirm the hypothesis that countries with a good investment environment for firms are those with a stronger capacity to invest abroad and exploit comparative advantages due to reduced domestic transaction costs and investment constraints.

Finally, IP and the trade-related dimension are analysed simultaneously (M7-M9). Even for this case, the previous results are confirmed: IP is positive and statistically robust, especially for investing countries, whereas bilateral export flows continue to positively influence CDM investment decisions with an economic impact (coefficient values) that is comparable with those obtained with LO.[17]

Given the fact that gravity models account for several dimensions of bilateral relationships, these results might well be interpreted in distribution terms. In other words, controlling for a number of country-specific features, the direction of CDM investments into specific countries (which gives the dimension of distribution) is closely related to the direction of export flows, revealing that the higher the installed capacity to have commercial bilateral relationships, the higher the propensity to exploit facilitated transaction channels in CDM projects as well.

The final clear empirical finding concerns the reduced role played by MACs when accounting for IP (M7-M9). The large impact of IP in Annex I countries strongly reduces the explanatory power of all energy-related regressors, when MAC coefficients, above all, in both investors and host countries are no longer statistically robust.

The only driver of investment decisions that still maintains its role is renewable electricity production in investing countries. This result can be interpreted as a sign of the role played by domestic institutions, where the IP in Annex I countries, here, clearly gives a dimension of risk uncertainty in medium and long term decisions, which is extremely important in determining the development path of new green technologies where market profitability is strongly affected by long term profiles (Kalamova e*t al.,* 2012).

[17] It is worth mentioning that the number of effective observations given by empirical results is strongly lower than potential one. This is due to the structure of a gravity model itself, since it requires that all j countries are represented even if they have no bilateral flows for the whole period. In that case a zero value is given and in the NBRM model these observations are automatically dropped since a log transformed equation is estimated. As a robustness check for reduced observations, an econometric estimation of models M4-M6 (Table 3) and M7-M9 (Table 4) has been developed, where the dependent variable is represented by a pure binary information assuming value 1 if there is at least one project developed by each *i-th* investor in each *j-th* Non-Annex country, and zero otherwise. The econometric estimator here adopted is a panel probit model, and all results on bilateral trade remain robust and statistically significant.

The better the domestic investment environment, the larger the competitive advantages gained by firms in developing renewable electricity production and the larger their propensity to export these technologies in the form of CDM projects.

## 5. Concluding remarks

This paper is an attempt to explore the causes behind the uneven distribution of CDM projects, with a particular emphasis on the role played by bilateral trade relationships as drivers of the investment behaviours of investing countries.

Investing countries implement CDM projects only in a few emerging countries – namely Brazil, China, and India – thus substantially ignoring the role of CDM in promoting sustainable development in the least developed economies.

According to the descriptive picture of such uneven distribution, this paper emphasises the role played by already existing bilateral commercial relationships as a potential driver for investment decisions. The econometric results show that cost-effectiveness as a criterion for abatement efforts is not the only driving force influencing decisions on destination markets. Bilateral export flows from Annex I economies toward Non-Annex I countries explain a large portion of the geographical distribution of CDM projects.

Two ancillary conditions are also investigated. First, the presence of good institutions in developing countries is a crucial factor in hosting CDM projects. This is quite an expected result and largely debated at qualitative level when reasoning over the role played by MOU in the adoption of and compliance with contracts and agreements. At the same time, Annex I countries with a better investment environment are those countries with the highest propensity to invest in CDM. Second, the role played by the installed capacity to produce renewable energy has also been confirmed by the empirical results. This means that the countries with higher renewable energy production are the players in the international scene with larger competitive advantages in terms of investing in CDM.

Two policy implications follow from the results presented here. First, in order to overcome the uneven distribution of CDM investments, an ad hoc policy action is required to redistribute them in developing countries. A first response to this requirement is represented by carbon funds managed by the World Bank. However, the increasing concentration of CDM projects over the past five years reveals that this is still an ineffective tool in convincing private investment to re-direct towards the underdeveloped world. Hence, a reinforcement of compulsory rules for CDM destination toward the least developed economies must be implemented at global level. The ongoing climate change negotiations in a post-Kyoto world have clearly emphasized the growing role of developing countries in the climate change debate, as can be seen by their active role in the establishment of the Green Climate Fund (GCF) as a key policy instrument. By taking into account the distribution failure of the CDM instrument, it will be crucial to explicitly design the GCF functioning rules by shaping a specific criterion devoted to orienting the CDM towards poor economies.

The second policy implication is the need for an enhancement of the institutional framework in developing countries that host the CDM as a major factor in reducing transaction costs and the risk of uncertainty, thus providing a stable environment for investment decisions. An active role played by developed economies should see knowledge transfer, and not just technology transfer, as a major goal to be achieved in the future actions against climate change. One key issue could be the potential spillover effects from governing policy interventions in climate actions that might arise for the other sectors not directly involved in CDM actions. A better institutional environment in developing countries will surely facilitate CDM projects and could also improve trade or other investment bilateral relationships, thus fostering the economic development of poor economies. This could also increase the economic convenience for investors redirecting financial flows towards those countries in which institutions are better equipped for managing large-scale projects. Surprisingly, all these considerations should also account for a hard constraint that the CDM has recently faced. As emphasized by Bayer, Marcoux, and Urpelainen (2013), leveraging private capital for climate mitigation is not an easy task, because the low internal rate of returns of the projects derived from the very low price of Certified Emission Reductions (CERs) reduces the attractiveness of the CDM as an investment option. To some extent, it may be necessary to combine two policy issues: attracting investments and redirecting them towards the least developed economies. The low prices of CERs mainly arise from the somewhat bottle-necked carbon market, which in turn arises because of the insufficient efforts made by the international community to create a well-functioning international emissions trading system. In order to give the CDM a greater development impetus, several interconnected policy issues should be addressed simultaneously so as to obtain a proper combination of different policy instruments for achieving different policy objectives. During the new negotiations phase, policy makers should also reduce those influences that have derived from past negotiations and other international tables (e.g. the ongoing rounds of the World Trade Organisation) in order to reduce potentially harmful, path-dependent behaviours that will bring new inefficient (or second-best) solutions.

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**Appendix A – Data description and main statistics**

**Table A1 - Variable definition and data sources**

| Variable name | Definition | Source |
|---|---|---|
| | *Dependent variables* | |
| CDM Projects$_{ij}$ ($lnCDM_{ij,t}$) | Number of registered CDM Projects per year from country *i* to country *j* | UNFCCC |
| | *Regressors* | |
| CO2 emissions$_{i,j}$ ($ln\mathbf{M}_{ij,t-1}$) | Total CO2 emissions (kt) | World Bank (WDI) |
| Electricity production$_{i,j}$ ($ln\mathbf{M}_{i,j,t-1}$) | Total electricity production (kWh) | World Bank (WDI) |
| Electricity production (renewable)$_{i,j}$ ($ln\mathbf{M}_{i,j,t-1}$) | Electricity production from renewable sources (kWh) | World Bank (WDI) |
| GDP per capita$_{i,j}$ ($ln\mathbf{M}_{i,j,t-1}$) | GDP per capita(constant 2000 international$ at PPP) | World Bank (WDI) |
| Export$_{ij}$ ($lnT_{ij,t-1}$) | Bilateral export flows in monetary value (constant 2000 international$ at PPP) | UN-Comtrade |
| Law & Order$_{i,j}$ ($lnI_{i,j,t-1}$) | Law & Order Indicator | PRS Group |
| Investment Profile$_{i,j}$ ($lnI_{i,j,t-1}$) | Investment Profile Indicator | PRS Group |
| Distance$_{ij}$ ($lnD_{ij}$) | Bilateral distance in km (between capitals, great-circle formula) | CEPII |
| Language$_{ij}$ ($dLang_{ij}$) | Dummy variable to show countries that share a common language | CEPII |
| Nuclear energy consumption $_{i,j,t-1}$ ($lnN_{i,j,t-1}$) | Nuclear Energy Consumption as % of Total Energy Consumption | British Petroleum |
| EU$_i$ (Dum EU$_i$) | Dummy variable for *i* countries being member of the European Union | |

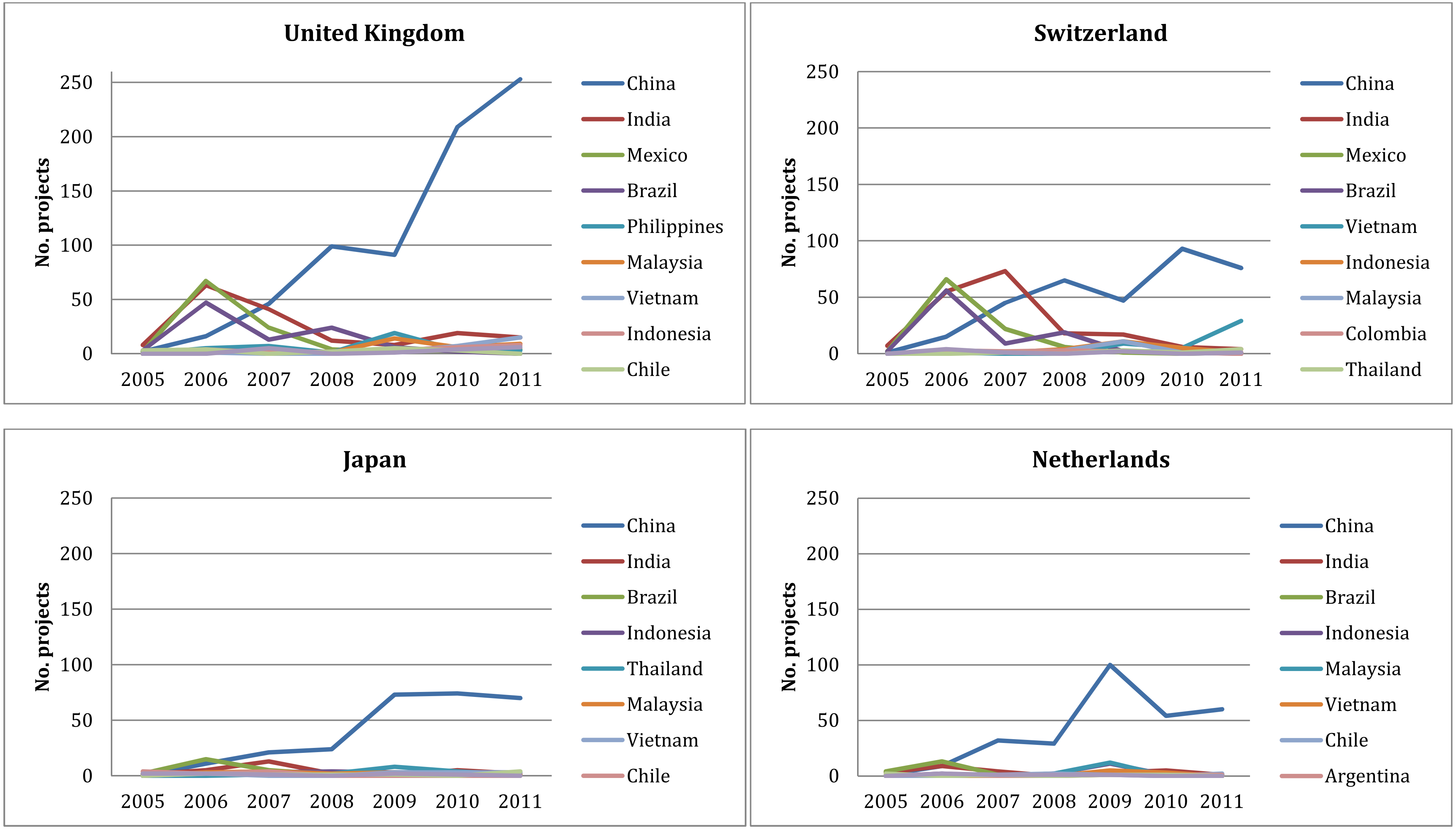
**Table A2 – Descriptive statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| $Distance_{ij}$ | 17,640 | 8.82 | 0.56 | 6.23 | 9.85 |
| $Language_{ij}$ | 17,640 | 0.15 | 0.35 | 0.00 | 1.00 |
| GDP per capita $_i$ | 14,994 | 10.18 | 0.35 | 9.36 | 10.94 |
| GDP per capita $_j$ | 14,580 | 7.25 | 1.37 | 4.51 | 10.48 |
| CO2 emissions $_i$ | 10,080 | 11.78 | 1.28 | 9.26 | 14.04 |
| CO2 emissions $_j$ | 10,000 | 9.06 | 2.18 | 4.70 | 15.77 |
| Electricity production $_i$ | 15,120 | 25.55 | 1.34 | 21.73 | 27.75 |
| Electricity production $_j$ | 8,980 | 23.41 | 1.77 | 18.49 | 28.94 |
| Electricity production (renewable) $_i$ | 15,120 | 23.96 | 1.57 | 19.17 | 26.68 |
| Electricity production (renewable) $_j$ | 7,800 | 21.62 | 2.47 | 13.82 | 27.19 |
| Nuclear energy consumption $_i$ | 17,640 | 0.54 | 2.43 | -2.30 | 3.68 |
| Nuclear energy consumption $_j$ | 17,640 | -2.14 | 0.69 | -2.30 | 2.72 |
| $Export_{ij}$ | 15,046 | 9.81 | 2.80 | -3.73 | 18.62 |
| Law & Order $_i$ | 17,640 | 2.39 | 0.11 | 2.08 | 2.48 |
| Law & Order $_j$ | 13,020 | 1.83 | 0.36 | 0.69 | 2.30 |
| Investment Profile $_i$ | 17,640 | 2.44 | 0.07 | 1.97 | 2.48 |
| Investment Profile $_j$ | 13,020 | 2.04 | 0.35 | 0.00 | 2.48 |

## Table A3 – Correlation matrix

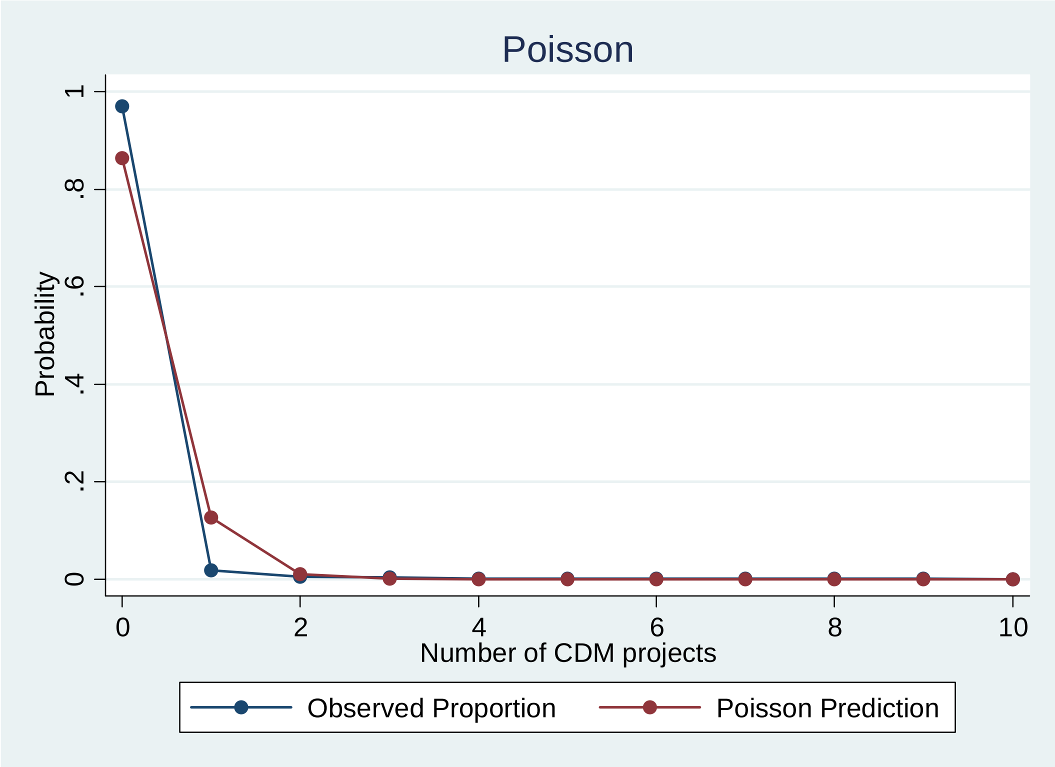
| | Distance ij | Common Language ij | GDP per capita i | GDP per capita j | CO2 emissions i | CO2 emissions i | Electricity production i | Electricity production j | Electricity production from renewables | Electricity production from renewables | Electricity production from nuclear | Electricity production from nuclear | Export flows ij | Law & Order i | Law & Order j | Investment Profile i |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common Language ij | 0.0608* | | | | | | | | | | | | | | | |
| GDP per capita i | -0.0388* | -0.0437* | | | | | | | | | | | | | | |
| GDP per capita j | 0.0063 | -0.0365* | 0.0064 | | | | | | | | | | | | | |
| CO2 emissions i | 0.0648* | 0.0332* | -0.2171* | 0.0005 | | | | | | | | | | | | |
| CO2 emissions i | -0.0541* | -0.1208* | 0.0058 | 0.3834* | 0.0005 | | | | | | | | | | | |
| Electricity production i | 0.0742* | 0.0034 | -0.2074* | 0.0021 | 0.9082* | 0.0019 | | | | | | | | | | |
| Electricity production j | 0.0821* | -0.0676* | 0.009 | 0.3675* | 0.0007 | 0.8917* | 0.0031 | | | | | | | | | |
| Electricity production from renewables i | 0.0815* | -0.0394* | -0.2057* | 0.005 | 0.5303* | 0.0036 | 0.7800* | 0.0078 | | | | | | | | |
| Electricity production from renewables j | 0.2379* | -0.1117* | 0.0044 | -0.0180* | 0.0004 | 0.4213* | 0.0016 | 0.6166* | 0.0042 | | | | | | | |
| Electricity production from nuclear power i | -0.0925* | 0.0138* | 0.2944* | -0.0003 | 0.2193* | -0.0003 | 0.2422* | -0.0005 | 0.0516* | -0.0002 | | | | | | |
| Electricity production from nuclear power j | 0.1040* | 0.0063 | -0.0001 | 0.1872* | 0.0001 | 0.4669* | 0.0001 | 0.5421* | -0.0002 | 0.3196* | 0.0002 | | | | | |
| Export flows ij | -0.2142* | 0.0062 | -0.0471* | 0.3551* | 0.4204* | 0.6440* | 0.4096* | 0.5439* | 0.2240* | 0.2196* | 0.2027* | 0.3178* | | | | |
| Law & Order i | 0.0897* | 0.0678* | 0.3785* | -0.0044 | -0.4323* | -0.0039 | -0.3793* | -0.007 | -0.2075* | -0.0039 | -0.1346* | 0.0017 | -0.2620* | | | |
| Law & Order j | -0.2030* | -0.0148* | 0.0006 | 0.3746* | -0.0009 | 0.1799* | -0.0011 | 0.0927* | 0.0009 | -0.1756* | 0 | 0.0002 | 0.1626* | 0.0067 | | |
| Investment Profile i | -0.0007 | 0.006 | -0.0186* | 0.0252* | 0.0280* | 0.0266* | 0.0176* | 0.0352* | 0.0145* | 0.0158* | 0.0804* | 0.0181* | 0.0470* | -0.0465* | -0.0305* | |
| Investment Profile j | -0.0564* | 0.0019 | 0.0067 | 0.4801* | 0.002 | 0.1084* | 0.0038 | 0.0956* | 0.0029 | -0.1208* | 0 | 0.0443* | 0.2168* | -0.008 | 0.2842* | 0.1031* |

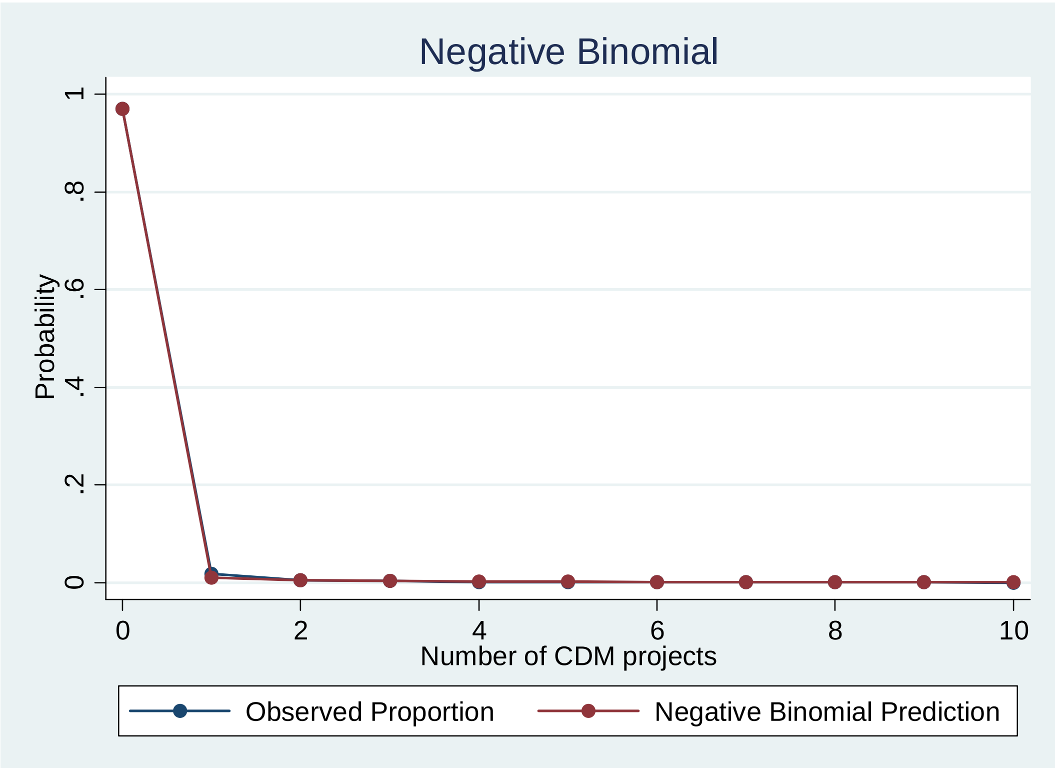
**Figure A1 – Distribution of CDM projects in host countries for the four top investors 2005-2011**




*Source: own elaboration on UNFCCC (2012).*

**Figure A2 – Robustness check for dependent variable CDM projects count: observed and predicted probability assuming a Poisson and a negative binomial univariate distribution**



# Interpreting bargaining strategies of developing countries in climate negotiations. A quantitative approach

## 1. Introduction

In 2007, during the COP13 held in Bali, the Parties started to negotiate for a new climate agreement to be implemented at the end of the first commitment period defined by the Kyoto Protocol (KP) in 2012 (UNFCCC, Decision 1/CP.13). Nevertheless, the so-called Bali Action Plan was too ambitious and the Parties failed to achieve a new binding agreement for all countries. As a result, the KP has been extended for a second commitment period (2013-2020), with the intent of reaching an agreement by 2015 for the implementation of a new climate regime to be effected in 2020.

Despite this failure, climate negotiations have been characterized by a remarkable novelty. While in the first phase the main objective was to get also reluctant Annex I countries to ratify the KP whereas developing countries' concerns remained marginal (Najam et al., 2003), in current negotiations developing countries have assumed a central role (Cantore et al., 2009; Ott et al., 2008).

The attention devoted to developing countries' interests results in two major decisions. The first one is the implementation of Nationally Appropriate Mitigation Actions (NAMAs), debated during COP16 (Cancun 2010) and COP17 (Durban 2011). By submitting country-specific NAMAs, developing countries can obtain support in terms of technology, financing and capacity-building transfer from economically advanced Parties to enable and facilitate their mitigation efforts.[18] The second achievement is represented by the institution of the Green Climate Fund (GCF), created to become the main financial instrument for promoting the adoption of mitigation and adaptation measures in developing countries (UNFCCC, Decision 1/CP.16; Decision 3/CP.17). The GCF, in particular, constitutes a great success for developing countries that have actively supported it (especially the ALBA group)[19] and have a strong representation in its current management structure.[20]

Other relevant decisions concerning developing countries were taken during COP19 held in Warsaw in 2013, such as the establishment of the Warsaw International Mechanism for Loss and

[18] This process is facilitated by the implementation of the NAMA registry, a web platform where developing countries publish their mitigation plans so that developed countries can decide whether to participate or not.
[19]The ALBA group consists of Bolivia and other Latin American and Caribbean countries with the exception of Brazil.
[20] 12 out of 24 Board members represent developing countries.

Damage (UNFCCC/CP/2013/L.15) intended to address the adverse impacts of climate change in developing countries that are expected to be particularly vulnerable to extreme events (IPCC, 2014).

In this complex scenario, the Parties seem to be far from reaching the main objective of negotiations: a new agreement for the implementation of an ambitious climate regime that limits average global warming to 2°C above pre-Industrial Revolution levels. The only step ahead is represented by the agreement signed at COP20 (Lima 2014), where the Parties agreed on the basic rules to be adopted in order to facilitate the Intended Nationally Determined Contributions (INDCs) that will form the foundation for climate action post 2020 when the new agreement expected in COP21 (Paris 2015) is set to come into effect. The regulation of INDCs constitutes a small contribution to escaping the deadlock, since they only suggest how Parties should contribute to the discussion in climate negotiations, without concrete solutions to the distribution of mitigation efforts and the allocation of investment resources.

The causes behind the deadlock are diverse and involve not only the huge projected global costs of achieving ambitious emission targets, but also the growing attention that vulnerability and adaptation issues are achieving in the political debate. Indeed, concerns about the costs of mitigation actions and equity considerations have highlighted the need for introducing compensatory measures and mechanisms to cope with unavoidable effects of climate change, in order to stimulate the participation of developing countries to international agreements.

A related argument behind the deadlock has been the emergence in climate negotiations of more differentiated positions compared with the traditional segmentation between developed and developing countries. In particular, the group of developing countries, which in the past proposed itself as extremely solid and unanimous, promoting a common interest in negotiations mainly under the umbrella of the G77 group, has become significantly fragmented (Brunnée and Streck, 2013; Hurrell and Sengupta, 2012). Fragmentation and conflicts of interests within the group have weakened the position of the great majority of developing countries, especially of those that are more vulnerable to climate change and that could benefit the most from the adoption of ambitious commitments. On the contrary, large emerging economies, such as China and India, frequently negotiate bilaterally with industrialised countries on issues such as climate, energy security and technology transfer, outside the official climate negotiations (Kasa et al., 2008). All these factors raise concerns about the possibility of reaching an agreement with the involvement of developing countries.

As it has become evident during the last COPs, developing countries have different expectations and concerns about climate change negotiations, reflecting huge differences with respect to their economic, political and human conditions (Gupta, 2008). Divisions within the group are expected to even exacerbate in the future, leading to the formation of new or differently shaped alliances that foster the common interest of countries' subgroups, especially with respect to the major issues at stake, namely emissions reduction obligations and vulnerability.

These recent trends in climate negotiations suggest the need of investigating the dynamics behind the emergence of new positions and alliances within the group of developing countries, especially in view of the run-up of a new climate agreement (Blaxekjær and Nielsen, 2014). Specifically, both similarities across developing countries and heterogeneities among different sub-groups need to be carefully evaluated in the development of compensatory measures to tackle climate change impacts (Tanner and Horn-Phathanothai, 2014). As far as the GCF is concerned, for instance, the allocation rule between adaptation and mitigation purposes should be part of the negotiations process; accounting for countries' specificities that affect mitigation costs or vulnerability to climate change could be the key to guarantee the involvement of developing countries (Markandya et al. 2015).

This paper explores the driving forces leading to the formation of alliances among sub-groups of developing countries, in order to support their position in the bargaining process with greater emphasis with respect to other big players (such as developed countries) or groups of players (such as the BASIC group). In this work, the formation of potential alliances is driven by countries' characteristics that are especially relevant to explain their positions and concerns about mitigation and adaptation efforts. To this end, we adopt a multiplicity of indicators referring to several dimensions (geography, economy, demography, energy, institutional quality, technological innovation and development), in order to capture the most relevant features that can affect each country's ability to cope with the main challenges of climate change.

The idea behind this quantitative analysis is that countries which share common characteristics will be interested in promoting the same position in climate negotiations; therefore, countries characterized by high level of vulnerability to climate change and low emissions, for instance, will be interested in pushing for stricter mitigation commitments and larger resources for adaptation. Accordingly, the hypothesis is that cohesion within countries forming an alliance depends on the degree of homogeneity with respect to climate change-related challenges. As stated by Kasa et al. (2008 p. 114): "a core element behind this cohesion is that these countries share problems related to varying degrees of political vulnerability as much as poverty and economic underdevelopment".

This idea is confirmed also by the emergence of new political groups and forums, such as the Climate Vulnerable Forum, the group of "Like-minded developing countries", or the Association of Independent Latin American and Caribbean Countries, whose narratives confirm that common interest is better represented and supported by countries that share similar problems with respect to the effects of climate change (Blaxekjær and Nielsen, 2014).

The focus is explicitly on developing countries, because of their growing role in recent climate negotiations and because their active involvement is strictly required for the implementation of an agreement that could be effective in slowing climate change. As noted above, developing countries are by no means a homogeneous group: some of them will have to engage in strong mitigation efforts, while others are likely to be seriously affected by climate change and will have to undertake a larger amount of adaptation. It is then essential to consider structural features and specificities of different developing countries to understand their main concerns in climate negotiations and increase their confidence in the fairness of the bargaining process.

Given this aim, the so-called emerging economies (the BASIC countries, i.e. Brazil, China, India, and South Africa) have been excluded from the analysis, not only because these countries, in latest years, have started to act as independent players in international agreements, but also because their interests in terms of abatement targets and adaptation needs are different from those of other developing countries.[21]

In order to study the formation of potential new alliances among developing countries, a cluster analysis is performed by exploiting a plurality of national specificities and structural features, and

[21] In several cases, separated negotiations between the major emerging economies and developed countries have worsened relationships among developing countries. As noted by Hurrell and Sengupta (2012, p.473): "At Copenhagen, the apparent entry of the BASICs into the closed councils of the most powerful caused intense resentment on the part of countries such as Bolivia. At Durban, the representatives of small island developing states were even more critical of an India that seemed to stand in the way of a final deal: 'While they develop, we die; and why should we accept this?'".

identify subgroups of countries, pooled together by reasonably homogeneous interests relevant for climate change issues. In such a way, it is possible to single out potential alliances that are expected to act as different "single" players, interacting with other groups of developing and developed countries to form new coalitions at climate negotiations.[22]

In this respect, this work complements studies that explore the issue of coalition stability by adopting the conceptual framework provided by the game-theoretic literature (see, for instance, Lessmann et al., 2015). These works generally assess coalitions' stability by performing numerical simulations, where a limited number of world's macro-regions is considered. Among them, developing countries are generally included in groups characterized by a high level of aggregation, where countries are combined on the basis of geographical reasons, or pooled together in a wide category labelled as the "Rest of the world" region. As suggested by the discussion above, however, these aggregations hide large heterogeneities across developing members, and ignore their differentiated viewpoints on climate policies. By accounting for countries' specificities, this analysis could also contribute to the improvement of such models, allowing for a more precise assessment of costs and benefits associated to alternative scenarios of active or passive participation of developing countries in climate actions.

By comparing the groups identified by applying the cluster analysis with existing informal groups and alliances of developing countries, it is also possible to investigate to what extent the two types of grouping overlap. By analysing overlapping and similarities, we can define the main determinants of the degree of internal cohesion of these alliances. Even though this study is not an attempt either to model the formation of coalitions (among developing countries' groups or between them and developed countries) or to investigate their stability, this analysis can provide useful insights to understand the bargaining position of different actors in climate negotiations, and can inform policy makers in designing compensatory measures that could help escaping the deadlock.

The rest of the paper is organized as follows. Section 2 presents a literature review concerning climate negotiations with a focus on developing countries. Section 3 describes the dataset and the

[22] An example of this type of coalition between groups of developing and developed countries is the Cartagena Dialogue for Progressive Action, which includes countries from EU, AOSIS, LDCs and Latin America. Nevertheless, the participants have a clear idea about the identity of the coalition, that is is a dialogue and not a formal political negotiation group. According to Yamin and Depledge (2004), the explanation of this attitude is that many developing countries find it difficult to be associated with developed countries in negotiations due to formal group memberships and a sense of loyalty to G77.

empirical methodology, Section 4 discusses the empirical results and Section 5 provides some concluding remarks.

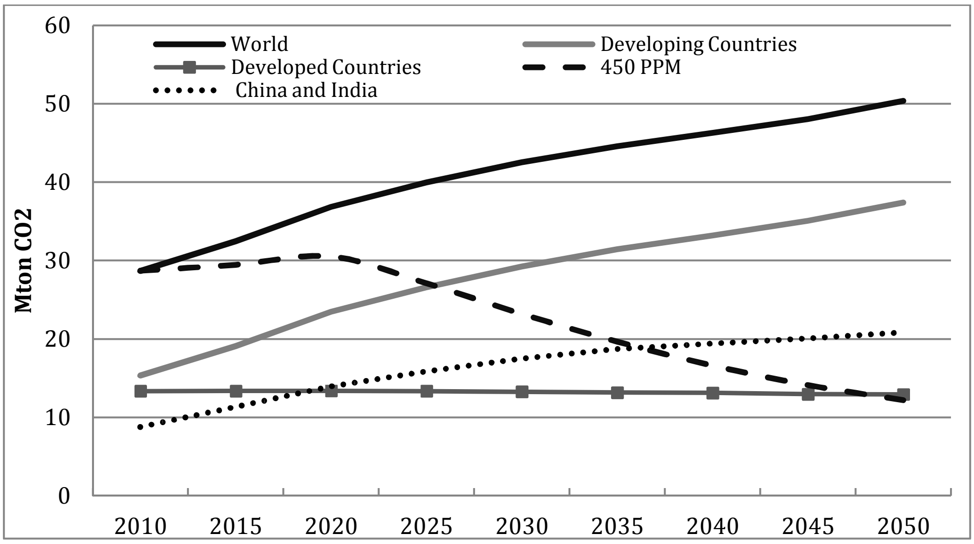
## 2. The climate change negotiations process

The issue of climate negotiations has been widely debated in recent years and several contributions have emphasized the need for a better understanding of the role and needs of developing countries whose interests have been systematically marginalized during the initial negotiation and implementation phase. The key interests of developing countries are the creation of an implementable and equitable climate regime within a sustainable development framework, as well as improvements in countries capacities to react to the effects of climate change, enhancing the adaptive capacity and resilience, especially of the more vulnerable countries (Najam et al., 2003; Sokona et al., 2002). The claim that mitigation must be accompanied by sustainable development, especially with regard to energy issues, has always been advocated by developing countries, also with regard to the Post-Kyoto debate: "a post-2012 regime that advances development goals sustainably must find a way to help provide the energy needed for development. But it must also find a way to help ensure that the energy in question does not lock us into decades of high-emission technologies" (Cosbey, 2009, p. 27).

With regard to climate change action, in recent years equity has been one of the most debated issues, being a highly contentious area of negotiation for the design of a 2015 agreement (Markandya, 2011; Mathur et al., 2014; Morgan and Waskow, 2014; Ngwadla, 2014). In particular, great emphasis has been given to the different interpretation of the Common But Differentiated Responsibilities (CBDR) principle and its consequences, both in terms of deadlock in negotiations and burden sharing implications (Winkler and Rajamani, 2014; Zhang and Shi, 2014). According to Article 3.1 of the Convention:"[t]he Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof." The CBDR principle can be considered the focal point of climate negotiations, its interpretation determining the burden sharing of emissions targets in the future climate regime.

Developing countries have interpreted responsibilities according to historic contributions to the climate problem, insisting on a rigid differentiation between developed and developing countries, and hence requiring rich nations to take on a bigger share of the burden for carbon cuts (Brunée and Streck, 2013). In contrast, developed countries have resisted the notion of historic responsibility as well as clear distinctions between North and South, focusing instead on current and future contributions to climate change and shifting the responsibility towards fast developing economies, such as China and India. Indeed, the share of GHG emissions by developing countries, and in particular emerging economies, is expected to substantially increase in the future, whereas emissions from developed countries are projected to remain fairly stable. Figure 1 shows the $CO_2$ emission flows target scenario of ensuring a stable concentration of GHGs in the atmosphere of 450 PPM by 2050, in order to limit average global warming to 2°C above pre-Industrial Revolution levels (Markandya et al., 2015). As a matter of fact, the increasing share over time of emissions associated with the development process of emerging and less advanced economies shows how crucial active involvement of the developing part of the world is in climate negotiations.

**Figure 1 - $CO_2$ emissions projections 2010-2050**




*Source: own elaboration on Markandya et al. (2015).*

Even though China and other developing countries have refused to make international commitments, considering past economic growth paths of industrialized countries responsible for climate change, it is clear that failing to engage developing countries in serious efforts at emissions reduction will have dramatic consequences for the possibility of controlling climate related problems. At the same time, the need to re-examine the CBDR and achieve a common interpretation of the principle in order to implement a new climate regime is also compelling (Bortscheller, 2010). Otherwise, the efforts of industrialized countries to actively involve developing countries in international climate negotiations may be regarded as a hostile act, or at least an indirect way to partly reduce the economic growth and development potential of less advanced economies (Rübbelke, 2011).

In order to convince developing countries to actively participate in climate negotiations and also play an active role in mitigation policies, their level of confidence in the fairness of the bargaining process must be raised. For this purpose, the role of adaptation support measures such as the implementation of the GCF or the improvement of financial aid aimed at technology transfer may be extremely beneficial in increasing this confidence. In other words, when industrialized countries finance adaptation actions, developing countries may feel treated more fairly and this in turn may have a positive impact on climate negotiations, especially with regard to their involvement in international mitigation efforts (Markandya et al., 2015). To this end, great expectations are placed on GCF functioning rules which are only partly established, especially with regard to distribution criteria among receiving countries and mitigation or adaptation purposes (Cui et al., 2014).

Several approaches have been developed in order to contribute to escaping the deadlock. Weiler (2012) investigates the determinants of bargaining success in climate change negotiations by adopting a political economy perspective, where success is defined by evaluating the coherence of the final decision with expectations on single bargaining coalitions. Specifically, bargaining success is measured as the distance from the state's original positions to the negotiated outcomes, also adjusted to account for the relevance of each negotiation issue. On the basis of these measures, he finds that countries' external power (measured by their GDP), their vulnerability to climate change, as well as the adoption of soft bargaining strategies for relevant issues, positively affect bargaining success, whereas assuming extreme positions and the state's share of emissions have a negative influence. It is worth noting that as GDP and the share of GHG emissions are correlated, they can have a peculiar role by pulling in different directions, one strengthening and one weakening a country's bargaining power. This could be strongly dependent on the technological capability of each country in the energy sector, since high

GDP levels might also be associated with a strong technological competitive advantage, and a pronounced decoupling effect. An example is represented by the EU, where the high level of economic development is associated to a strong policy commitment for clean energy systems.

According to Harstad (2012), countries with weak technological capabilities are those facing higher compliance costs, and thus they represent parties with a weak bargaining position. This highlights the crucial role of an additional element related to technological capabilities of developing countries, which are themselves explained by a large number of different elements characterizing the economic system at the domestic level (Archibugi and Coco, 2004). The question of identifying what constitutes bargaining power in climate coalitions is related to the definition of “relevance”. By enlarging the focus in order to consider other indicators of relevance in addition to the share of global GDP, such as a country’s share of global emissions and share of global population, it is possible to include other countries as “relevant” to contribute to collective problem-solving (Falkner, 2015).

In order to assess the relative bargaining power of different coalitions, it is necessary to fully understand the characteristics of the countries forming the groups. Along these lines, Kasa et al. (2008) analyse countries’ specificities and provide interesting insights into understanding the positions of developing countries in climate negotiations. While poverty and other common problems related to economic and political underdevelopment have been driving factors behind the formation of the G77 as a group and the maintenance of unitary positions in the early period of the climate regime, the increasing economic heterogeneity among members has led to the emergence of bilateral agreements between the richest developing countries (such as Brazil, China, and India) and the major advanced countries on relevant climate and energy issues. This new type of cooperation weakens the position of the rest of the developing countries, especially those that would benefit most from the adoption of universal, strict commitments, since they are the most vulnerable to the adverse impacts of climate change.

There is no agreement in the scientific literature about what factors determine bargaining success or failure. According to Weiler (2012), there are two ways of evaluating the success of an international negotiation process. The first refers to a success that consists in a final agreement, preferably followed by a legal document. The second consists in appraising to which extent a party has influenced the outcome of the negotiations. In analysing this second aspect, the strategic choices in climate change negotiations have been mainly investigated with respect to the party specific success, without a quantitative analysis of the underlying preferences driving bargaining positions of parties.

A different strand of literature that investigates the formation of coalitions and their stability is based on game theoretical modelling. Specifically, contributions that use integrated assessment models to obtain simulation results for heterogeneous players show that in the absence of transfer schemes, the incentive to stay in a coalition depends on two main factors: the region's abatement potential and its exposure to climate change damages (see, for instance, Lessmann et al., 2015; Nagashima et al., 2009; Weikard et al., 2010). Accordingly, the preference for remaining in a coalition is larger for countries that have low abatement potential (i.e. steep marginal abatement cost function and hence a low mitigation burden) and high marginal damages (i.e. larger benefits from increased coalitional abatement). In other terms, common characteristics related to country's efforts can explain positive incentives to participate in a coalition. In the presence of transfer mechanisms, asymmetries among players become relevant to explain different incentives to participate.

This study draws on this literature by considering countries' specific aspects that are relevant for explaining their position toward mitigation burden and abatement benefits. Further, alliances identified in this work can be seen as single players that interact with other actors (both developed and emerging economies), on the basis of their respective benefits and costs from abatement. In this respect, this study suggests more disaggregated groups of developing countries that can be used in integrated assessment models to improve the regional articulation.

In order to disentangle different positions and to trace out potential alliances among developing countries, this study draws on the methodology developed by Costantini *et al*. (2007) which explores the bargaining positions of developing countries in World Trade Organization (WTO) negotiations by assuming that the under-lying preferences of parties can be proxied by the structural features of parties with respect to the specific issue under negotiation. Individual countries are expected to join coalitions on the basis of similar expected benefits that arise from a specific negotiation outcome. Thus, member countries of existing coalitions should present a certain degree of homogeneity with regard to a set of variables related to the aspects covered by the negotiation process under scrutiny.

As emphasized in Depledge (2008), it is possible to define the concept of salience as how important climate change is for a country, which in turn depends heavily on the expected consequences of a changing climate for a given country.

Going beyond the measurement approach proposed by Depledge (2008) based on the amount of efforts exerted by a government in discussing at the national level the climate change issues, the quantification adopted in this study is relative to several dimensions influencing both vulnerability to climate change and vulnerability to mitigation costs. According to Hasson *et al.* (2010), the mitigation vs. adaptation investment remains an unsolved dilemma. This quantitative exercise allows also reflecting on how different countries or groups of similar countries are positioned with respect to this dilemma, partly explaining the instability of bargaining coalitions. In order to reach a consensus on a final global agreement, such differences should be carefully accounted for. As a matter of fact, if compensatory measures might be the right way to reach stable coalitions, it is necessary to design differentiated measures in order to minimize defection risk.

## 3. The empirical methodology

### *3.1. Dataset description*

In the case of climate negotiations, relevant country features relate to several aspects, such as the vulnerability to climate change, the current and projected level of GHG emissions, the level of technological capabilities, the availability of knowledge capital and so forth. Hence, in order to cluster countries with respect to their interests in climate negotiations, the choice of the variables that form the dataset to be used in subsequent analysis is a preliminary step.

Given the purpose of this analysis, the countries considered in this study present the following characteristics with respect to a multilateral climate regime: i) they have relatively low abatement commitments; ii) they have poor technological capabilities; iii) they might gain substantial benefits from compensatory measures, such as technology transfer and adaptation funds.

This choice guarantees that the statistical sample includes countries that can form quite homogeneous alliances. According to the theoretical assumptions described in the previous sections, this homogeneity could represent a key element of stability in future negotiations, since it is a proxy of their expectations with respect to the negotiations outcomes. A deep knowledge of the elements explaining such homogeneity, and consequently the bargaining power of such groups, could inform the negotiation process on those compensation measures able to incentivise an active participation of such groups to the negotiation process.

Accordingly, the statistical analysis has been carried out on a sample of 89 countries, where two driving criteria are used for the selection: i) the ratification of the Kyoto Protocol as Non-Annex I Parties; ii) the availability of information covering all the selected structural features for the years 2011-2013.[23] For all the considered countries, several variables representing different country features have been included in order to reduce subjectivity bias in the statistical results as much as possible. In addition, the average value of variables in the period 2011-2013 is considered, in order to avoid the biasing effect of fluctuations. In particular, 55 variables have been selected, that can be divided into seven dimensions: geography, economy, demography, energy, institutional quality, technological innovation and development. The complete list of variables used in the analysis and data sources are provided in Table A1, Appendix A.

**1. Geography.** This dimension includes all homogeneously available physical characteristics related to geography, including, among others, surface area, length of coastline and temperature. Special attention has been devoted to climatic characteristics, related to the degree of vulnerability to climate change of each country and other crucial aspects in climate negotiations. The main statistical source for geographical information is the World Bank, with the exception of the Vulnerability Index and the "Index of projected precipitation impact".

The first one is provided by the University of Notre Dame together with the Readiness Index in order to calculate the ND-GAIN (Notre Dame Global Adaptation Index), an index that represents the degree of vulnerability to climate change and a country's readiness to adaptation (University of Notre

[23] Countries included in the analysis are: Algeria, Argentina, Armenia, Azerbaijan, Bahrain, Bangladesh, Benin, Bolivia, Botswana, Burkina Faso, Cambodia, Cameroon, Chile, Colombia, Comoros, Congo, Republic, Costa Rica, Cote d'Ivoire, Cuba, Dominican Republic, Ecuador, Egypt Arab Republic, El Salvador, Ethiopia, Gabon, Gambia, Georgia, Ghana, Guatemala, Honduras, Indonesia, Iran Islamic Republic, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyz Republic, Lao PDR, Lebanon, Madagascar, Malawi, Malaysia, Maldives, Mali, Mauritius, Mexico, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Qatar, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Sri Lanka, St. Lucia, St. Vincent and the Grenadines, Sudan, Suriname, Swaziland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkmenistan, Uganda, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

Dame, 2013).[24]

To evaluate the impact of projected precipitation, the "Index of projected precipitation impact" has been constructed in three steps. First, the average value between the minimum and the maximum projected precipitation values has been calculated as an indicator of "rain direction" (a positive average value indicates a probability that precipitation will increase and vice versa). Second, on the basis of the "Mean annual precipitation per squared km", a coefficient has been assigned to each country in order to classify all countries from the driest (5) to the wettest (-5). Finally, this coefficient has been multiplied by the average value between the minimum and the maximum projected precipitation measure previously calculated, obtaining the "Index of projected precipitation impact" that has been normalized in order to assume values from 0 (negative impact) to 1 (positive impact).[25]

**2. Economy.** This dimension provides a comprehensive representation of the economic structure of each country, containing information on GDP, employment, exports, FDI and many other aspects. All data are taken from the World Bank WDI online database.

**3. Demography.** Several measures regarding population issues constitute this dimension, such as, for instance, the number of inhabitants, the growth rate, and the share of female or rural population. Here too, the source of data is represented by the World Bank WDI.

**4. Energy.** This dimension contains information on the energy sector, such as energy and electricity production and consumption, as well as information on the use of renewable energies. Data come from the World Bank WDI tool and the EIA (Energy Information Administration) online data service. This dimension also includes the level of $CO_2$ emissions from fuel combustion (as defined by IEA, 2013); accurate data for developing countries are taken from the World Bank WDI tool.

**5. Institution:** As a proxy for the quality of institutions, data from the Political Risk Services Index (PRI), provided by the PRS Group (2014), have been used. In particular, four indicators of political and socio-economic characteristics have been selected: Socioeconomic Conditions (SE), Investment Profile (IP), Law and Order (LO) and Democratic Accountability (DA). Since the maximum values of the

[24] 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.

[25] A negative impact is registered, for example, if precipitation is expected to increase in very wet countries and decrease in very dry ones and vice versa (positive impact if precipitation decreases in wet countries and if it increases in dry ones).

indices are different (6 for LO and DA; 12 for IP and SE), in order to conduct the analysis, values have been normalised to a common 12 maximum value.

**6. Technological Innovation.** This dimension contains information on infrastructure endowments as well as on technology diffusion, including road density, number of internet users, number of telephone lines, and degree of specialization in high technology exports. All data are taken from the World Bank WDI.

**7. Development.** This dimension consists of indicators focused on aspects related to climate issues. Accordingly, variables included in this dimension refer to poverty, income distribution, the well-being level as designed in the human development framework, and public policies for basic needs, such as health and education. The sources of these data are the World Bank and the UNDP. The Human Development Index (HDI) is also included. It is one of the most widely used indicators of development, calculated by the UNDP on the basis of the country's average achievements in three dimensions: a long and healthy life, access to education and a decent standard of living.

### *3.2. Cluster analysis*

The methodology used to classify developing countries in homogeneous groups on the basis of the previously described dimensions is a cluster analysis. This is a "generic term for procedures that seek to uncover groups in data" (Everitt et al., 2001, p. 5). In other words, it allows for the identification of groups of units that are similar to each other within the group, but different from units that belong to other groups.

Given the multiplicity of variables adopted in this study and in order to avoid potential correlations between variables in the cluster procedure, a preliminary Principal Component Analysis (PCA) on the original dataset is performed.[26] PCA is a technique for reducing the dimensionality of datasets by extracting only the information that is strictly necessary for representing the variance of the phenomena. Accordingly, it replaces the original variables by a smaller number of derived variables, the principal components (PCs), which are linear combinations of the original variables (Jolliffe, 2005).

Several methods can be used to select the number of PCs to be retained. The most widely used in

[26] Table A2 in Appendix A shows the Kaiser-Meyer-Olkin test. An overall value higher than 0.5 suggests the use of a PCA.

literature are: i) the Kaiser criterion, according to which the components to be selected are those with eigenvalues greater than 1 (Hsieh et al., 2004; Kaiser, 1960); ii) the cumulative percentage of total variation criterion (Lee et al., 2006; Mazzanti and Montini, 2014). As illustrated by Jolliffe (2002), it consists in selecting the number of components that explains an established variance threshold level. This level should be in the range 70% to 90%, assuming lower values when the number of variables is high. Following this criterion and given that, according to Jackson (1993), this method can overestimate the number of PCs, a fairly low threshold has been chosen in this study. In particular, two attempts have been made to apply the cluster analysis to two different numbers of PCs that explain 75% (11 PCs) and 80% (13 PCs) respectively of the cumulative variance. With a threshold level at 80%, countries are classified into seven clusters, whereas with a 75% threshold, the optimal number of clusters is seven or nine. It is also worth mentioning that in the case of seven clusters, the specific countries entering the groups are almost totally overlapping by choosing 11 or 13 PCs. Accordingly, the cluster analysis has been performed by selecting 11 or 13 PCs in order to select the most stable and robust results.[27]

The cluster analysis is conducted in two steps. The first one consists of a hierarchical cluster analysis that is needed to determine the optimal number of clusters. When the number of clusters is defined, the second step consists of using the number of clusters to inform a non-hierarchical clustering process by imposing the number of clusters obtained in the first step.

With regard to the first step of the cluster analysis, the process of hierarchical clustering consists of four phases (Johnson, 1967): i) to assign each item to a cluster so that there are N clusters, each containing just one item; ii) to find the closest (most similar) pair of clusters and merge them into a single cluster so that there is one cluster less; iii) to compute distances (similarities) between the new cluster and each of the old clusters; iv) to repeat phases two and three until all items are clustered into a single cluster of size N. Phase three can be done in different ways which is what distinguishes alternative methods. The method used in this analysis is Complete Linkage, according to which the distance between one cluster and another cluster is equal to the greatest distance from any member of one cluster to any member of the other cluster. This is computed in terms of the Euclidean distance,

[27] See Appendix B

defined as the square root of the sum of squares of the differences between the coordinates of the points. Once the complete hierarchical tree was obtained, in order to choose the optimal number of clusters (k), the Duda-Hart test was conducted (Duda and Hart, 1973) and interpreted according to Cao et al. (2008). The implementation of this test gives as a result a matrix made of three columns: the first column represents the number of clusters, the second column provides the corresponding Duda–Hart Je(2)/Je(1) index stopping-rule,[28] whereas the third one gives the pseudo-T-squared values. From the comparison of these two values, as already mentioned, seven and nine are found to be the best numbers of clusters, as they have a high Duda–Hart Je(2)/Je(1) value (0.92 and 0.88, respectively) associated with a low pseudo T-squared value (3.62 and 4.00, respectively).[29] Thus, the analysis was carried for both seven and nine clusters. Results show that there are no substantial differences between the composition of groups which are the same with the exception that two clusters become part of two others when considering seven groups. Thus, in order to choose the best number of clusters, considerations regarding the dataset structure must be made. In particular, it is worth noting that it is composed of variables that explain the overall structure of countries but it does not include mere geodesic information (e.g. latitude and longitude) that otherwise would have driven the cluster analysis. As a result, the classification that has been chosen is the one that has the best geographical representation, namely the one with nine clusters.

Thus, after the implementation of the Complete Linkage hierarchical tree, the optimal number of PCs representing the dataset here explored is 11, and the optimal number of clusters is nine.

This is the final number of clusters implemented in the second step of the cluster analysis, consisting of a non-hierarchical k-means clustering in which the number of groups must be pre-determined and aims to minimize the sum of the distances of each item from the centroid of its cluster, thus the intra-cluster variance (MacQueen, 1967).[30] At the end of the process, the final composition of the nine clusters is achieved.

[28] The Duda–Hart Je(2)/Je(1) index is the ratio between the total within sum of squared distances about the centroids of the clusters for the two-cluster solution (Je(2)) and the within sum of squared distances about the centroid when only one cluster is present (Je(1)).

[29] See Table A3 in Appendix A.

[30] The k-means algorithm is made up of four phases: i) to determine the centroids; ii) to calculate the distance between cluster centroid to each object and assign each object to a cluster based on the minimum distance; iii) to compute the new centroid of each group based on the new memberships; iv) to repeat phases two and three until the assignments no longer change.

## 4. Cluster analysis results feeding the political economy discussion

### *4.1. Definition of climate clusters*

According to the three-step analysis described in Section 3, the 89 developing countries selected in the dataset can be pooled into nine groups, where Table 1 describes the final composition of each.

**Table 1 – Groups of developing countries from cluster analysis**

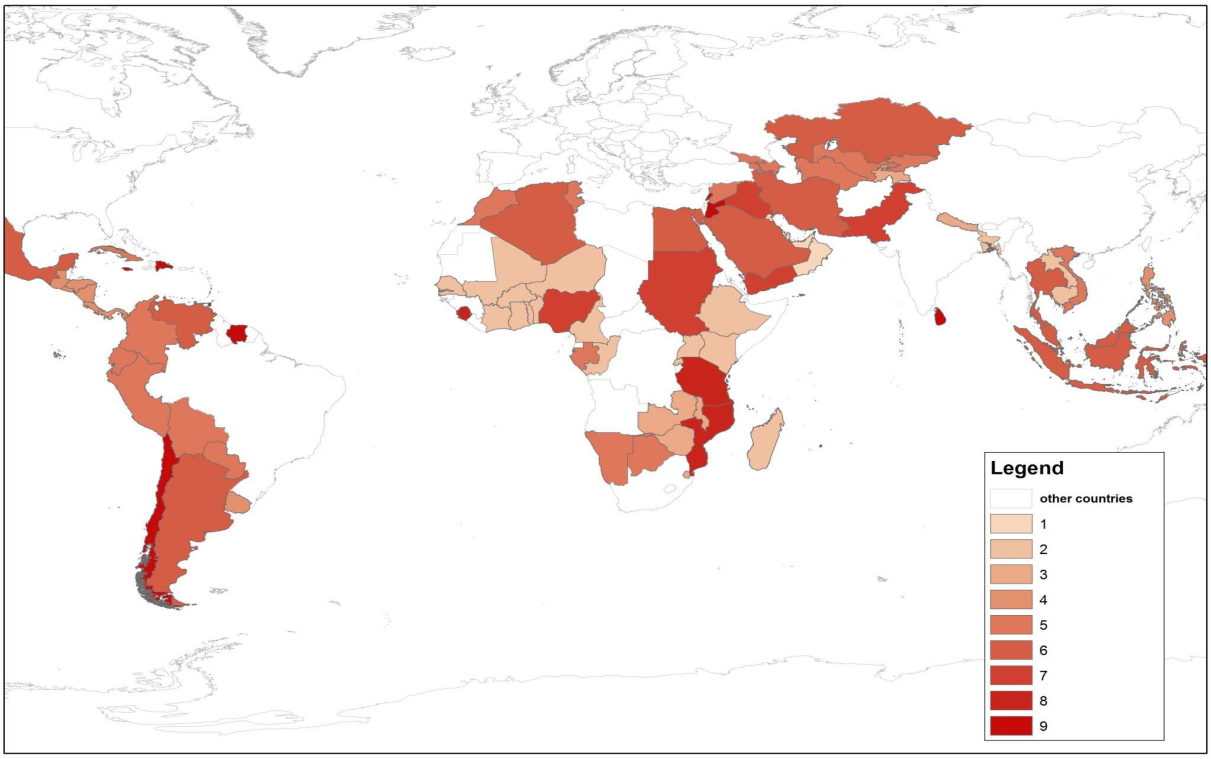
| Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 | Cluster 8 | Cluster 9 |
|---|---|---|---|---|---|---|---|---|
| Bahrain | Benin | Malawi | Costa Rica | Bolivia | Argentina | Nigeria | Mozambique | Chile |
| Kuwait | Burkina Faso | Swaziland | El Salvador | Colombia | Mexico | Sudan | Sierra Leone | Dom. Rep. |
| Oman | Cameroon | Zambia | Guatemala | Cuba | Venezuela | Iraq | Tanzania | Jamaica |
| Qatar | Comoros | Zimbabwe | Honduras | Ecuador | Algeria | Pakistan | | St. Lucia |
| Un. Arab Em. | Congo, Rep. | Nepal | Nicaragua | Paraguay | Egypt | Yemen | | St. V. & Gren. |
| | Cote d'Ivoire | Tajikistan | Panama | Peru | Indonesia | | | Suriname |
| | Ethiopia | | Uruguay | Botswana | Iran | | | Trin. & Tob. |
| | Gambia | | Philippines | Gabon | Kazakhstan | | | Mauritius |
| | Ghana | | | Morocco | Malaysia | | | Jordan |
| | Kenya | | | Namibia | Saudi Arabia | | | Lebanon |
| | Madagascar | | | Tunisia | Thailand | | | Maldives |
| | Mali | | | Armenia | | | | Sri Lanka |
| | Niger | | | Azerbaijan | | | | |
| | Rwanda | | | Georgia | | | | |
| | Senegal | | | Kyrgyz Rep. | | | | |
| | Togo | | | Syr. Arab Rep. | | | | |
| | Uganda | | | Turkmenistan | | | | |
| | Bangladesh | | | Uzbekistan | | | | |
| | Cambodia | | | Vietnam | | | | |
| | Lao PDR | | | | | | | |

Cluster 1 and 6 include small and large energy exporting economies, respectively. Whereas Cluster 6 is composed of countries not belonging to the same geographical area, Cluster 1 also has a common geographic feature since it gathers countries located only in the Middle East. A geographic feature also drives Cluster 3 that includes all landlocked countries, and Cluster 9, that mainly consists of islands. Cluster 5 seems to be mainly driven by countries' endowment of natural resources, whereas Cluster 7 includes countries with serious problems of political instability and low institutional quality. Finally, the world's poorest countries are split into two different clusters: the poorest African economies mainly based on mineral resources constitute Cluster 8, whereas the others belong to Cluster 2.

By looking at Figure 2, the spatial representation of clusters distribution reveals that the African continent shows the highest heterogeneity with countries assigned to a relative higher number of clusters than other continents. This provides a first overall view of the increasing importance that less advanced countries actively participate in a final global agreement. If several contrasting interests gather a large number of countries, it could be difficult to reach a consensus without several compensating schemes for more vulnerable countries.

In order to analyse the nine clusters we select some indicators for each dimension included in the dataset, referring to the original data and not on the PCA components, for a description of real structural features characterizing each group. The selection process of the indicators reported in Table 2 is based on the computation of the mean value for each variable within countries inside each cluster calculated on country-specific normalized values with respect to the mean value for each variable. By taking normalized rather than original indicators, differences among clusters emerge independently from the size of the indicator under scrutiny. Accordingly, the mean value for each cluster allows describing the singular group with respect to the others. In addition, we compute the standard deviation of the mean values (based on normalized values) for the nine clusters (reported in the last Column of Table 2) for each variable composing the whole dataset. The three indicators for each dimension with the higher value of standard deviation are selected, by considering that the higher the value of the standard deviation, the higher the dispersion among mean values across clusters, the stronger the influence of the variable in driving the formation of the groups.[31]

**Figure 2 - Developing countries' bargaining coalitions from cluster analysis**




[31] A higher value of the standard deviation calculated on mean values for each cluster proxies a greater distance between centroid of each cluster explained by that specific indicator under scrutiny. The larger the distance among centroids, the more the clusters are well defined and distinguished from the others. Accordingly, those variables expressing a larger distance correspond to what allows clusters to form and to be stable.

## Table 2 – Driving variables

| Dimension | Index | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 | Cluster 8 | Cluster 9 | St.Dev. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Geography | Precipitation (mm per sq km) | 0.28 | 0.50 | 0.10 | 0.26 | 0.04 | 0.01 | 0.00 | 0.10 | 6.15 | 2.00 |
| | Coastline (km) | 0.44 | 0.22 | 0.00 | 2.56 | 0.52 | 3.81 | 0.45 | 0.68 | 0.48 | 1.28 |
| | Extreme events (% pop affected) | 0.51 | 1.49 | 3.91 | 0.54 | 0.67 | 0.53 | 0.60 | 1.35 | 0.28 | 1.13 |
| Economy | GDP (bln$ PPP const 2011) | 1.06 | 0.23 | 0.11 | 0.53 | 0.61 | 4.37 | 2.03 | 0.16 | 0.32 | 1.38 |
| | FDI inflows (% GDP) | 0.37 | 1.01 | 0.59 | 1.11 | 0.92 | 0.48 | 0.29 | 4.42 | 1.43 | 1.27 |
| | Employment in agric. (% of tot empl.) | 0.08 | 1.67 | 1.91 | 0.69 | 0.86 | 0.51 | 1.22 | 2.00 | 0.35 | 0.70 |
| Demography | Population (mln) | 0.14 | 0.96 | 0.48 | 0.65 | 0.64 | 2.53 | 3.17 | 0.95 | 0.20 | 1.06 |
| | Population growth (%) | 2.61 | 1.35 | 1.19 | 0.76 | 0.67 | 0.70 | 1.18 | 1.28 | 0.47 | 0.63 |
| | Rural population (% of tot. pop.) | 0.22 | 1.34 | 1.55 | 0.77 | 0.87 | 0.67 | 1.18 | 1.39 | 0.99 | 0.42 |
| Energy | Electr. prod. Renew. (% of tot. elect. prod.) | 0.00 | 0.69 | 0.05 | 6.11 | 0.37 | 0.55 | 0.00 | 0.00 | 1.09 | 1.96 |
| | Energy production (Mtoe) | 2.91 | 0.06 | 0.04 | 0.06 | 0.59 | 4.69 | 1.65 | 0.07 | 0.10 | 1.66 |
| | $CO_2$ emissions (Mton) | 1.35 | 0.11 | 0.06 | 0.28 | 0.64 | 5.03 | 1.28 | 0.06 | 0.29 | 1.59 |
| Institution | Socio-economic conditions (score) | 1.73 | 0.66 | 0.62 | 1.08 | 1.19 | 1.33 | 0.56 | 0.59 | 1.10 | 0.4 |
| | Law & Order (score) | 1.52 | 0.94 | 0.98 | 0.80 | 1.11 | 0.97 | 0.74 | 1.23 | 0.94 | 0.24 |
| | Democratic accountability (score) | 0.81 | 0.92 | 0.89 | 1.43 | 0.77 | 1.03 | 1.02 | 1.27 | 1.24 | 0.23 |
| Technology | Road density (km per 100 sq. km of land area) | 3.54 | 0.69 | 0.44 | 0.95 | 0.48 | 0.45 | 0.40 | 0.20 | 2.54 | 1.16 |
| | High-technology exp. (% of tot. exports) | 0.19 | 0.68 | 0.83 | 2.55 | 1.06 | 1.66 | 0.12 | 1.59 | 0.44 | 0.80 |
| | Internet users (per 100 people) | 2.64 | 0.29 | 0.48 | 1.08 | 1.11 | 1.43 | 0.63 | 0.12 | 1.52 | 0.78 |
| Development | Mortality rate - under 5 (% live births) | 0.21 | 1.79 | 1.65 | 0.48 | 0.69 | 0.41 | 1.75 | 2.41 | 0.38 | 0.81 |
| | Malnutrition (% of children under 5) | 0.38 | 1.81 | 1.32 | 0.61 | 0.56 | 0.50 | 2.12 | 1.50 | 0.58 | 0.65 |
| | Health expenditure, public (% of GDP) | 0.47 | 0.94 | 1.11 | 1.33 | 1.00 | 0.80 | 1.01 | 1.83 | 1.03 | 0.37 |

*Notes: values reported for each cluster and indicator come from the following statistical treatment. First, the original data for each country have been scaled with the mean value of the same indicator calculated for all 89 countries forming the panel. This procedure allows reducing the dependency from pure scale effects in differentiating countries. Second, such scaled values have been used for calculating an average value among countries forming each cluster. The last Column of Table 2 then reports the standard deviation calculated on the basis of mean values assumed by each cluster, indicator by indicator.*

Quite interestingly, variables related to Energy, Geography and Economy dimensions have higher values of standard deviation, whereas variables referring to Demography, Institution and Development have lower values. This suggests that the first three dimensions can play a major role in determining the composition of clusters than the others. All variables identified in Table 2 are crucial to the formation of bargaining coalitions in the context of climate negotiations. Geographical variables (precipitation, coastline and extreme events), for example, represent characteristics strictly related to the vulnerability of a country. At the same time, economic conditions, characteristics of the energy systems and emission levels explain potential concerns about reduction obligations and justify different requests in terms of the implementation of compensatory measures. Economies largely dependent on energy exports, for instance, could be negatively affected by the adoption of stringent abatement objectives, which can have the effect of reducing international energy prices due to demand restrictions. Generally, results show that the clusterization process is mainly driven by those characteristics that represent the most debated issues in international climate negotiations. This suggests that specific country features must be considered in order to foresee potential new alliances or defections based on countries' common or divergent interests.

*4.2. Climate bargaining strategies of developing countries*

Statistical results help to explain the bargaining interests of developing countries and compare existing countries' alliances and coalitions and the groups derived by the cluster analysis, in order to highlight potential hot spots in climate agreements. Starting with fossil fuels exporters (Cluster 1 and 6), it is worth mentioning that these countries have a strong interest in avoiding economic losses that may arise as a consequence of mitigation actions. As a large decrease in international fossil fuel demand will substantially reduce net gains for energy exporters, they have a clear interest in assuming negotiating positions intended to limit mitigation actions. It is worth noting that efforts made by these countries to delay and prevent the implementation of mitigation actions are also justified by their low level of vulnerability to the negative effects of climate change. Compared with other developing countries, energy exporters (Cluster 1 and 6) are the countries with the highest GDP per capita associated with the lowest degree of vulnerability, as illustrated in Table 3 (which reports cluster-specific mean values in absolute terms for selected indicators).

At the same time, however, these two clusters would have very different abatement costs in a mitigation scenario, since their emissions are significantly diverse, both in terms of levels and as a share of overall $CO_2$ emissions (corresponding to 1.23% and 10.07% of total $CO_2$, respectively). It is therefore reasonable to presume that their efforts to contrast the introduction of mitigation actions will also be differentiated according to these costs. Specifically, highly polluting energy exporters have a double interest in maintaining low levels of abatement duties, which can benefit them both indirectly, through the maintenance of international demand for fossil fuels, and directly, by reducing their contribution to overall abatement efforts. Negotiating positions of countries within Cluster 1 and 6 could also be different with respect to the debate on GCF allocation, with strong polluters calling for funding criteria that privilege compensation of mitigation efforts over adaptation measures.

**Table 3 – Comparison between GDP per capita, $CO_2$ emissions and vulnerability of clusters**

| Cluster No. | GDP p.c. ($ PPP const 2011) | Vulnerability Index | $CO_2$ (Mton) | Share of world $CO_2$ (%) | Fuel exports (% of tot exp) | Institution quality | No. of countries |
|---|---|---|---|---|---|---|---|
| 1 | 71,586 | 0.31 | 413.23 | 1.23 | 76.77 | 8.20 | 5 |
| 2 | 2,231 | 0.51 | 129.71 | 0.39 | 11.18 | 5.52 | 20 |
| 3 | 2,751 | 0.46 | 20.73 | 0.06 | 3.99 | 5.04 | 6 |
| 4 | 9,935 | 0.36 | 135.66 | 0.40 | 2.14 | 7.01 | 8 |
| 5 | 9,788 | 0.35 | 744.44 | 2.21 | 33.17 | 6.19 | 19 |
| 6 | 19,146 | 0.30 | 3,385.08 | 10.07 | 48.72 | 6.59 | 11 |
| 7 | 6,386 | 0.49 | 390.99 | 1.16 | 73.72 | 5.18 | 5 |
| 8 | 1,424 | 0.55 | 10.42 | 0.03 | 9.88 | 6.49 | 3 |
| 9 | 14,334 | 0.34 | 213.18 | 0.63 | 8.67 | 7.03 | 12 |

By interpreting the average GDP per capita as a criterion to evaluate the level of external power in negotiations (Nagashima *et al.*, 2009), Cluster 1 is by far the strongest coalition among developing countries, with the highest expected success in bargaining process. At the same time, since the UNFCCC works with the one country one vote rule, Cluster 6 is formed by a larger number of countries than Cluster 1, and it represents the most unfavourable one to a stringent mitigation commitment, since it will face large direct mitigation costs relative to other Clusters and will also face a large loss in fossil fuel export flows.

Clusters 2, 3 and 8 are the poorest and most vulnerable groups. They include countries (especially

African States) characterized by very low levels of economic development and agricultural performance, low quality in the institutional and infrastructural context, and, conversely, a high vulnerability to desertification and extreme weather events. Therefore, their main interests are to foster the fight against climate change, as well as to promote a climate regime that combines climate efforts and sustainable development. Due to their high vulnerability combined with very low levels of $CO_2$ emissions, they may be interested in negotiating the implementation of strict abatement efforts and national measures that force larger emitters to a more significant cut in GHG emissions. In fact, Table 3 shows that, despite the multiplicity of countries included, Clusters 2, 3 and 8 are all characterized by low levels of $CO_2$ emissions (and low percentages in terms of overall emissions, corresponding respectively to 0.39, 0.06 and 0.03 per cent), associated with the highest degree of vulnerability (here represented by the aforementioned Vulnerability Index). While confirming one of the main tensions associated with climate change, i.e. countries most affected by the negative impacts of climate change are those that are not responsible for it, these considerations also provide a potential interpretation of recent changes in negotiation alliances towards more differentiated positions. Indeed, it is quite evident that these countries will try to negotiate the allocation of more financial resources to adaptation rather than mitigation support. At the same time, if we interpret vulnerability as the inverse of the concept of "patience" taken from the bargaining literature, it follows immediately that these countries, being the more vulnerable/less patient, have the lowest bargaining power in negotiations (Rubinstein, 1982). The high degree of impatience of the most vulnerable countries can be exploited by other countries, which could try to obtain most of the gains from the climate agreements, for instance, by bargaining modest emission abatement targets or requiring larger funds for compensating mitigation costs, in exchange for a rapid conclusion of the agreement. In this scenario, the implementation of measures, such as the provision of financial resources for adaptation purposes or the transfer of risk management competences, could have the role of strengthening the bargaining power of the most vulnerable alliances of developing countries.

Cluster 4 and 5 include countries characterized by low levels of vulnerability. Cluster 4 is also geographically homogenous, consisting mainly of Latin American States. These two clusters are discussed together because they include several countries belonging to the same existing negotiating coalitions, namely the ALBA and AILAC,[32] which have played an active role in recent climate meetings. However, as the cluster analysis suggests, these alliances encompass countries with different geographical and economic characteristics that can potentially affect their positions within the coalition and can lead to future defections. Countries in Cluster 4, for instance, have a longer relative coastline than Cluster 5 (see Table 2), signalling a higher exposition to the negative effects of global warming. On the other hand, they contribute to a lower share of global emissions (0.40% compared with 2.21%) and fuel exports (as reported in Table 3). These aspects may give rise to different attitudes in climate negotiations, with countries grouped in Cluster 4 that advocate stronger mitigation actions or, at least, an allocation of GCF that is more unbalanced towards adaptation support.

By looking at Cluster 7, we can see that it consists of five countries, namely Nigeria, Sudan, Iraq, Pakistan and Yemen, characterized by high political instability, terrorism, a high crime rate and corruption, as demonstrated by the low value of the indicator for the quality of institutions. From the climatic bargaining point of view, they represent a very interesting group, because, although they have a high level of fuel exports, they can be classified as poor and vulnerable countries when comparing their GDP per capita and Vulnerability Index. This suggests that they may have conflicting interests and positions in climate negotiations depending on the main direction adopted in future agreements. In fact, on the one hand, they may benefit from stricter abatement efforts that may reduce the expected adverse effects of climate change; on the other, their economies are strongly linked to fossil fuels exports and a reduction in global consumption would seriously threaten their opportunities of economic growth. These contrasting interests can lead these countries advocating different positions, joining alternative bargaining coalitions (LDCs as well as fossil fuel producers) during different COPs. These considerations also suggest that, whatever the final outcomes in negotiations, they will probably experience some losses, since they have to sacrifice improvements in terms of vulnerability in favour of economic benefits or vice versa.

The same contrasting positions characterize countries belonging to Cluster 9: as shown in Table 3, they have a relatively high GDP per capita and $CO_2$ emissions compared with other clusters formed by

[32] ALBA (Bolivarian Alliance for the Peoples of Our America) includes Antigua and Barbuda, Bolivia, Cuba, Dominica, Ecuador, Grenada, Nicaragua, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines and Venezuela, while AILAC (Independent Alliance of Latin America and the Caribbean) includes Chile, Colombia, Costa Rica, Guatemala, Panama and Peru.

LDCs, combined with a low general vulnerability, even though they are highly vulnerable to the risk of flooding and sea level rise (as shown by Table 2 values). Due to these considerations, we can expect them to be interested in a new agreement for a greater effort in adaptation as well as mitigation actions, even though it would imply their active contribution in mitigation efforts. At the same time, they will advocate more funds for adaptation purposes, requiring special investment efforts in actions oriented towards reducing the specific climate risk of sea level rise.

As suggested by statistical cluster results, developing countries are characterized by heterogeneous concerns and conflicting interests that can contribute to explaining the deadlock in climate negotiations. In particular, the analysis reveals that in some circumstances, countries may advocate, at the same time, interests that are potentially contrasting, leading to the possibility that very fragile, variegate and unstable alliances will be formed. This has become particularly evident in recent years when several new sub-groups (more or less formalized) have been created in order to defend their interests. New negotiating blocks include, for instance, the BASIC countries (Brazil, South Africa, India and China) which include emerging and large emitting countries and the LDCs, group, including the more vulnerable countries. Other alliances are the Central American Integration System (SICA), the AILAC, the ALBA, the Alliance of Small Island States (AOSIS) and the Group of like-minded (GLM) developing countries (Roberts and Edwards, 2012). However, these coalitions are strongly influenced by the heterogeneity of their members and are expected to be highly unstable. The AOSIS group, for example, is composed of islands that are threatened by climate change in very different ways; clearly, their degree of involvement in climate efforts is different and individual interests may differ from those representing the coalition's common interests (Betzold, Castro and Weiler, 2012). This is particularly relevant if we consider that, in recent years, some negotiating blocks (Latin American blocks, in particular) have been able to influence climate negotiations, determining deadlocks as well as important decisions such as the implementation of the GCF.

As seen above, when we compare existing alliances and coalitions with clusters, we can observe that there is no perfect overlapping between them. If we look at AILAC and ALBA groups, for instance, we can see that their member countries belong to three different clusters (Cluster 4, 5 and 9), whereas Venezuela belongs to Cluster 6.

Differences in countries' distribution among the clusters reflect potential weaknesses in existing bargaining coalitions and suggest that potential hot spots and critical situations may arise. By looking, for instance, at Nicaragua and comparing it with the rest of ALBA members, we can observe that it has a lower level of emissions (4.54 against an average value of the group of 28.82 Mton), a higher percentage of electricity production from renewable sources (22% against 2%) and higher energy imports (83% against 19% of energy use). Furthermore, these values are more similar to those for other AILAC members grouped in Cluster 4. Colombia and Peru, on the other hand, are more similar to ALBA members since their data show higher values than those associated with AILAC countries.

These different structural features of member countries can lead to the adoption of different positions in the bargaining process. Consequently, divergent interests might create problems for the stability of existing alliances, complicating the negotiation process and leading to a standstill.

## 5. Conclusions

In recent years we have seen the emergence of several new bargaining groups within climate negotiations and the scientific literature has poorly emphasized their crucial role in producing or escaping from a deadlock. Given the heterogeneity of countries included in these bargaining groups and their relative differences in the costs and benefits related to climate actions, it is reasonable to presume that future climate negotiations will be characterized by more nuanced and unstable alliances. According to Carraro et al. (2006), large asymmetries in the distribution across countries of costs and benefits associated to climate change and mitigation issues may lead to a reduction in expected gains from participating at a global treaty, thus increasing defection rates and free riding behaviours. Consequently, the design of an "optimal sharing rule" of costs and benefits is a necessary condition to ensure coalition stability (Weikard, 2009; Weikard and Dellink, 2014). This issue is particularly timely in view of the deadline for a global climate agreement at COP21 which will be held in Paris in December 2015.

In light of this emerging debate, the analysis identifies the main driving factors behind countries' interests and concerns and provides a sketch of future potential bargaining positions. As the analysis suggests, countries belonging to different groups can have different attitudes towards mitigation and adaptation issues, depending on their specificities in terms of socio-economic and geographical aspects that determine their relative peculiarities and vulnerabilities.

The comparison of the groups formed by the statistical cluster approach proposed here with the already existing bargaining coalitions emphasizes that the relative position toward mitigation vs. adaptation support and with respect to the stringency level of future mitigation pathways is highly dependent on the structural features that characterize single countries.

The different sources of such heterogeneity emerged from the cluster analysis should inform the policy design effort in finding an optimal sharing rule of costs and benefits. Given this high heterogeneity, the policy implication is that, in order to maximize the likelihood of a successful climate agreement in the short term, it will be necessary to design differentiated supporting actions according to countries' specific interests and weaknesses in order to reduce the gap between costs and benefits of mitigation policies and vulnerability to climate change.

Accordingly, the policy advice is that the already existing compensation mechanisms, primarily the GCF, should be better designed in order to become useful in reducing the distance between the domestic optimal solution desired by each country from the climate negotiations and the final global agreement achieved. The GCF, or whatever complimentary supporting measure will be adopted, should be interpreted not only as a compensation instrument, but also as an active tool for facilitating a successful international climate agreement.

Consequently, the distribution criteria across countries and objectives (mitigation vs. adaptation; different types of adaptation costs) should be planned according to quantitative assessment analysis instead of following requirements from unstable bargaining coalitions.

To this purpose, this paper also provides some suggestions with respect to informing ex-ante evaluation models in order to better specify regional aggregation respecting the under-lying preferences of actors with respect to climate change issues, in order to build up payoff matrices more coherent with real costs and benefits. This will allow better computing also those complimentary efforts required to reduce conflicts in negotiations thus reaching to a global climate agreement more rapidly.

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## Appendix A

### Table A1 – Dataset description and data sources

| Dimension | Variable | Definition | Source |
|---|---|---|---|
| **Geography** | Surface | Surface area (sq. km) | World Bank |
| | Coastline | Coastline(km) | CIA-World Factbook |
| | Agricultural land | Agricultural land (% of land area) | World Bank |
| | Annual temperature | Mean Annual temp. (Celsius) | World Bank |
| | Daily min temperature | Average daily min temperature (1961-1990, Celsius) | World Bank |
| | Daily max temperature | Average daily max temperature (1961-1990, Celsius) | World Bank |
| | Projected temperature change | Projected mean annual temperature change (average2045-2065, Celsius) | World Bank |
| | Temperature % variation | Temperature percentage variation | Own elaboration on World Bank data |
| | Annual precipitation | Mean Annual prec (mm per sq km) | World Bank |
| | Precipitation impact | Index of projected precipitation impact | Own elaboration on World Bank data |
| | Droughts, floods, extreme temperatures | % pop. Affected by extreme events (avg. 1990-2009) | World Bank |
| | Vulnerability Index | Vulnerability Index (ND-Gain) | University of Notre Dame |
| **Economy** | GDP | GDP, PPP (current international $) | World Bank |
| | GDP growth | GDP growth (annual %) | World Bank |
| | Gross fixed capital formation | Gross fixed capital formation (% of GDP) | World Bank |
| | General government final consumption expenditure | General government final consumption expenditure (% of GDP) | World Bank |
| | Unemployment, total | Unemployment, total (% of total labour force) | World Bank |
| | Employment, agriculture | Employment in agriculture (% of total employment) | World Bank |
| | Employment, industry | Employment in industry (% of total employment | World Bank |
| | Employment, services | Employment in services (% of total employment) | World Bank |
| | Employment, female | Employment to pop. ratio, 15+, female (%) | World Bank |
| | FDI | FDI, net inflows (% of GDP) | World Bank |
| | Exports | Exports of goods and services (% of GDP) | World Bank |
| **Demography** | Population | Population (Total) | World Bank |
| | Population growth | Population growth (annual %) | World Bank |
| | Population, 0-14 | Population ages 0-14 (% of total) | World Bank |
| | Population, female | Population, female (% of total) | World Bank |
| | Rural population | Rural population (% of total population) | World Bank |

## Table A1 – Dataset description and data sources - continued

| | | | |
|---|---|---|---|
| **Energy** | Electricity production | Electricity production (kWh) | World Bank |
| | Electricity production from oil, gas and coal sources | Electricity production from oil, gas and coal sources (% of total) | World Bank |
| | Electricity production from renewables | Electricity production from renewable sources, excluding hydroelectric (% of total) | World Bank |
| | Energy Production | Total Primary Energy Production (Mtoe) | EIA |
| | Energy Consumption | Total Primary Energy Consumption (Mtoe) | EIA |
| | Energy imports | Energy imports, net (% energy use) | Own elaboration on EIA data |
| | Fossil fuel energy consumption | Fossil fuel energy consumption (% of total) | World Bank |
| | Fuel exports | Fuel exports (% of merchandise exports) | World Bank |
| | Fuel imports | Fuel imports (% of merchandise imports) | World Bank |
| | CO2 emissions | CO2 emissions (kt) | World Bank |
| **Institution** | Socioeconomic Conditions | Socioeconomic Conditions | The PRS Group |
| | Investment Profile | Investment Profile | The PRS Group |
| | Law and Order | Law and Order | The PRS Group |
| | Democratic Accountability | Democratic Accountability | The PRS Group |
| **Technical innovation** | Road Density | Road Density (km of road per 100 sq. km of land area) | World Bank |
| | Internet users | Internet users (per 100 people) | World Bank |
| | Mobile-cellular subscriptions | Mobile cellular subscriptions (per 100 people) | World Bank |
| | Telephone lines | Telephone lines (per 100 people) | World Bank |
| | High-technology exports | High-technology exports (% of manufactured exports) | World Bank |
| **Development** | Schooling | Mean years of schooling | UNDP |
| | Education expenditure | Education exp, public (%GDP) | UNDP |
| | Health expenditure | Health exp, public (%GDP) | UNDP |
| | Under 5 mortality rate | Under-five mortality rate (per 1,000) | World Bank |
| | Child malnutrition | Child malnutrition, underweight (% of under age 5) | World Bank |
| | Life expectancy | Life expectancy at birth (year) | UNDP |
| | Distribution | 2000-2010 Quintile Income Ratio (q20%) | UNDP |
| | HDI | Human Development Index | UNDP |

## Table A2 – Kaiser-Meyer-Olkin Test

| Variable | KMO | Variable | KMO |
|---|---|---|---|
| Surface | 0.5285 | Electricity production | 0.8036 |
| Coastline | 0.5824 | Electricity production from oil, gas and coal sources | 0.6726 |
| Agricultural land | 0.6099 | Electricity production from renewables | 0.476 |
| Annual temperature | 0.6177 | Energy Production | 0.7439 |
| Daily min temperature | 0.5928 | Energy Consumption | 0.7309 |
| Daily max temperature | 0.5862 | Energy imports | 0.7896 |
| Projected temperature change | 0.4906 | Fossil fuel energy consumption | 0.8508 |
| Temperature % variation | 0.4457 | Fuel exports | 0.6524 |
| Annual precipitation | 0.3982 | Fuel imports | 0.6164 |
| Precipitation impact | 0.1234 | CO2 emissions | 0.7599 |
| Droughts, floods, extreme temperatures | 0.5692 | Socioeconomic Conditions | 0.7384 |
| Vulnerability Index | 0.835 | Investment Profile | 0.746 |
| GDP | 0.7507 | Law and Order | 0.3169 |
| GDP growth | 0.4009 | Democratic Accountability | 0.338 |
| Gross fixed capital formation | 0.3697 | Road Density | 0.6232 |
| General government final consumption expenditure | 0.4179 | Internet users | 0.776 |
| Unemployment, total | 0.3672 | Mobile-cellular subscriptions | 0.7693 |
| Employment, agriculture | 0.7948 | Telephone lines | 0.8243 |
| Employment, industry | 0.783 | High-technology exports | 0.2693 |
| Employment, services | 0.7498 | Schooling | 0.7021 |
| Employment, female | 0.7494 | Education expenditure | 0.5136 |
| FDI | 0.5512 | Health expenditure | 0.5115 |
| Exports | 0.5773 | Under 5 mortality rate | 0.8407 |
| Population | 0.5687 | Child malnutrition | 0.7729 |
| Population growth | 0.5745 | Life expectancy | 0.808 |
| Population, 0-14 | 0.7592 | Distribution | 0.4033 |
| Population, female | 0.5911 | HDI | 0.7553 |
| Rural population | 0.8608 | **Overall** | **0.6908** |

## Table A3 – Duda-Hart Test

| Number of clusters | Je(2)/Je(1) | pseudo T-squared |
|---|---|---|
| 1 | 0.8585 | 14.51 |
| 2 | 0.9409 | 4.96 |
| 3 | 0.334 | 13.96 |
| 4 | 0.7375 | 27.76 |
| 5 | 0.6857 | 14.67 |
| 6 | 0.0107 | 92.1 |
| 7 | 0.924 | 3.62 |
| 8 | 0.8128 | 9.9 |
| 9 | 0.8787 | 4 |
| 10 | 0.878 | 4.86 |
| 11 | 0.3693 | 3.42 |
| 12 | 0.8321 | 5.45 |
| 13 | 0.5096 | 5.77 |
| 14 | 0.8361 | 5.29 |
| 15 | 0.741 | 6.64 |

## Appendix B

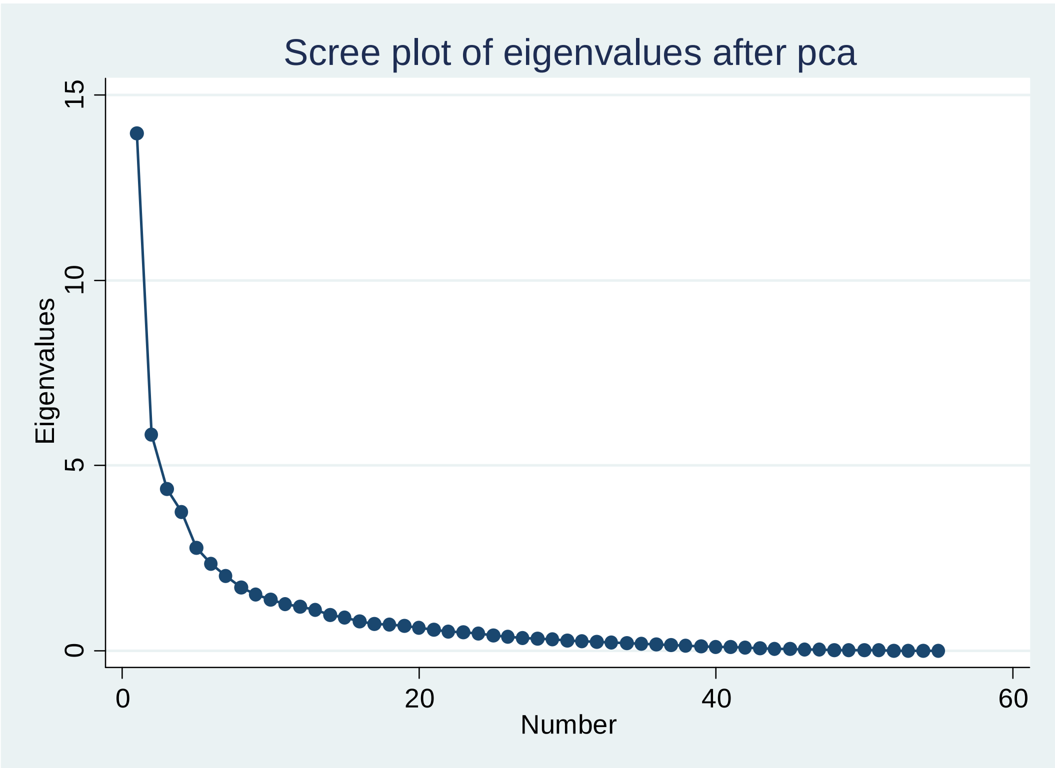
### Table B1 – Principal Component Analysis

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|---|---|---|---|---|
| Comp1 | 13.9636 | 8.12905 | 0.2539 | 0.2539 |
| Comp2 | 5.83457 | 1.46191 | 0.1061 | 0.36 |
| Comp3 | 4.37266 | 0.619227 | 0.0795 | 0.4395 |
| Comp4 | 3.75343 | 0.977334 | 0.0682 | 0.5077 |
| Comp5 | 2.7761 | 0.435791 | 0.0505 | 0.5582 |
| Comp6 | 2.34031 | 0.319883 | 0.0426 | 0.6007 |
| Comp7 | 2.02042 | 0.305421 | 0.0367 | 0.6375 |
| Comp8 | 1.715 | 0.199695 | 0.0312 | 0.6687 |
| Comp9 | 1.51531 | 0.136213 | 0.0276 | 0.6962 |
| Comp10 | 1.37909 | 0.125811 | 0.0251 | 0.7213 |
| Comp11 | 1.25328 | 0.0635398 | 0.0228 | 0.7441 |
| Comp12 | 1.18974 | 0.0834806 | 0.0216 | 0.7657 |
| Comp13 | 1.10626 | 0.13583 | 0.0201 | 0.7858 |
| Comp14 | 0.970432 | 0.0761036 | 0.0176 | 0.8035 |
| Comp15 | 0.894328 | 0.104373 | 0.0163 | 0.8197 |
| Comp16 | 0.789956 | 0.0592832 | 0.0144 | 0.8341 |
| Comp17 | 0.730673 | 0.0268099 | 0.0133 | 0.8474 |
| Comp18 | 0.703863 | 0.0265199 | 0.0128 | 0.8602 |
| Comp19 | 0.677343 | 0.0507078 | 0.0123 | 0.8725 |
| Comp20 | 0.626635 | 0.0596105 | 0.0114 | 0.8839 |
| Comp21 | 0.567025 | 0.0475373 | 0.0103 | 0.8942 |
| Comp22 | 0.519487 | 0.0225454 | 0.0094 | 0.9036 |
| Comp23 | 0.496942 | 0.0341481 | 0.009 | 0.9127 |
| Comp24 | 0.462794 | 0.057737 | 0.0084 | 0.9211 |
| Comp25 | 0.405057 | 0.0240391 | 0.0074 | 0.9284 |
| Comp26 | 0.381018 | 0.0370376 | 0.0069 | 0.9354 |
| Comp27 | 0.34398 | 0.0135268 | 0.0063 | 0.9416 |
| Comp28 | 0.330453 | 0.0259445 | 0.006 | 0.9476 |
| Comp29 | 0.304509 | 0.0236289 | 0.0055 | 0.9532 |
| Comp30 | 0.28088 | 0.0227291 | 0.0051 | 0.9583 |
| Comp31 | 0.258151 | 0.0248713 | 0.0047 | 0.963 |
| Comp32 | 0.233279 | 0.0146996 | 0.0042 | 0.9672 |
| Comp33 | 0.21858 | 0.00779917 | 0.004 | 0.9712 |
| Comp34 | 0.210781 | 0.0175138 | 0.0038 | 0.975 |
| Comp35 | 0.193267 | 0.0268224 | 0.0035 | 0.9785 |
| Comp36 | 0.166444 | 0.0111667 | 0.003 | 0.9816 |
| Comp37 | 0.155278 | 0.0215066 | 0.0028 | 0.9844 |
| Comp38 | 0.133771 | 0.0086886 | 0.0024 | 0.9868 |
| Comp39 | 0.125082 | 0.0160836 | 0.0023 | 0.9891 |
| Comp40 | 0.108999 | 0.00709431 | 0.002 | 0.9911 |

**Table B1 – Principal Component Analysis – continued**

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|---|---|---|---|---|
| Comp41 | 0.101905 | 0.0192065 | 0.0019 | 0.9929 |
| Comp42 | 0.082698 | 0.0123063 | 0.0015 | 0.9944 |
| Comp43 | 0.0703917 | 0.013685 | 0.0013 | 0.9957 |
| Comp44 | 0.0567067 | 0.0112216 | 0.001 | 0.9967 |
| Comp45 | 0.0454851 | 0.0114263 | 0.0008 | 0.9976 |
| Comp46 | 0.0340588 | 0.00880458 | 0.0006 | 0.9982 |
| Comp47 | 0.0252542 | 0.00299057 | 0.0005 | 0.9986 |
| Comp48 | 0.0222636 | 0.00289839 | 0.0004 | 0.999 |
| Comp49 | 0.0193653 | 0.010165 | 0.0004 | 0.9994 |
| Comp50 | 0.00920021 | 0.000307679 | 0.0002 | 0.9996 |
| Comp51 | 0.00889253 | 0.00179767 | 0.0002 | 0.9997 |
| Comp52 | 0.00709486 | 0.0038407 | 0.0001 | 0.9999 |
| Comp53 | 0.00325416 | 0.000736487 | 0.0001 | 0.9999 |
| Comp54 | 0.00251767 | 0.000403114 | 0 | 1 |
| Comp55 | 0.00211456 | . | 0 | 1 |

**Figure B1 – Eigenvalues after PCA**



## *Assessing costs and benefits of current climate negotiations*

### 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 deals (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.[33]In spite of

[33] 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.

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, 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 at 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

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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.

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[34] and officially launched the following year at COP 17.[35] 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 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%).[36] In May 2015, the signed contributions reached the 50% threshold (USD 5.5 billion)[37] 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.[38] 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). As argued in the second paper, in fact, given the strong heterogeneity of developing countries, 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'

[34] Decision 1/CP.16
[35] Decision 3/CP.17
[36] GCF/B.09/08
[37] GCF (2015), Status of Pledges and Contributions made to the Green Climate Fund, Status Date: 21 May 2015.
[38] GCF/B.09/08

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. 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 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) 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, the GTAP model developed in this work combines both the cost of climate change and a compensatory measure.

## 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 and 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 (Markandya et al., 2015).

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 a more well-structured 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, 23 regions and 21 sectors are considered. With regard to the former, following the Kyoto Protocol scheme, this study differentiates 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 can 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, 21 industries are distinguished: 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. [39]

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

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

*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 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 estimation of the cost of climate change have been made. One of the first attempts is represented by the Mendelsohn model[40] 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,

[40] Mendelsohn et al. (1998)

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[41]. With regard to country-level studies, the most recent is the one conducted by Arndt et al. (2015) for Vietnam. By 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[42] 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, which are representative of four areas: environmental disasters, habitat change, health impact and industry stress.[43] 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

[41] 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

[42]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.

[43] See Table A1 in Appendix A

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).[44] 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 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 into the model.[45]

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.

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

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".[46] 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

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

[45] 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.

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

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,[47] but it is in line with those that calculate the decay rate due to natural processes in about 3ppm per year.[48] 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, the stock of $CO_2$ can not be calculated endogenously by applying (1). Accordingly, the atmospheric concentration enters the model as an exogenous variable. In particular, NOAA historical data inform the model until 2010,[49] then further projections are taken from IPCC, as a simple mean between results obtained from different models applied to the IPCC A1 Scenario.[50]

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.

$$CCM_t = \frac{CCT}{STCO} \tag{2}$$

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.

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

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.

$$CCT = CCM_t \cdot STCO \tag{4}$$

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

[47] See http://euanmearns.com/the-half-life-of-co2-in-earths-atmosphere-part-1/
[48] See http://www.hydrogen.co.uk/h2_now/journal/articles/2_global_warming.htm
[49] NOAA estimates the concentration of CO2 in the atmosphere at 393.07 ppm in 2007 and at 401.09 in 2010.
[50] IPCC (2007)

increase of more than 3°C, in a range from 2.4°C to 5.5°C (IPCC, 2007).[51] 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), an average loss of 4% of global GDP is found.[52]

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 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).[53] 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.[54] 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.[55]

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[51] See Table A2 in Appendix A

[52] 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.

[53] University of Notre Dame (2013)

[54] 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%).

[55] 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

The regional cost of climate change represents the value associated to the negative externality caused by climate change and it considerably affects the economy by reducing wealth. 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), "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[56] 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.

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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.

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

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

$$INCOME = PRIVEXP + GOVEXP + SAVE - CCR \tag{6}$$ [57]

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, p. 32), emissions can enter the model exogenously. This methodology perfectly runs in a static context. Unfortunately, in a dynamic analysis, the high impact on GDP due to the cost of climate change prevents the model to reach a proper calibration. Since a solution to this calibration issue is still pending, in results shown in Section 4 the cost of climate change (CCR) is deducted from GDP and EV ex post.

### *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

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

(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, the global economy is projected 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, the last two scenarios are built in accordance with the 450 ppm target and 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 equal 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:

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

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, the GCF is modeled to reproduce 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)[58] according to their GDP

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

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. Consequently, the distribution of adaptation resources is modeled by using the variable VULN previously described, adjusted to represent the vulnerability of a region relative to the total vulnerability of developing countries.

$$vuln = \frac{VULN_m}{\sum VULN_m} \tag{9}$$

Furthermore, as GCF rules currently ask for the allocation of 50% of adaptation resources to LDCs, *vuln* is adjusted 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): [59]

$$vuln_W = 0.5 \cdot \frac{vuln_S}{\sum vuln_S} \tag{10}$$

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.

$$shf = \frac{gdp + vuln_W}{2} \tag{11}$$

[59] Least Developed Countries are here represented by six regions, namely RAF, RAF2, RAM, RAS, RAS2 and VNM.

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

## 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.

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.[60]

**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,

[60] See Table B2 in Appendix B

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%.

**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 |

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 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).

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.

**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 |

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.

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.

**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 |

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 from the ethical and descriptive approach, respectively.[61]

[61] 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).

**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 |

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 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, from a general perspective, welfare improvements are registered for the GET-550 Scenario.[62] 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 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 |

[62] 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.

**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 |

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).

**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 |

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. 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. Accordingly, all emerging economies but India receive most of resources for mitigation purposes.

**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* |

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 adaptation needs.

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.

**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* |

In order to better investigate the two scenarios and their effects on receiving countries, Table 11 shows a comparison between the two allocation methods. The difference between them reveals whether the 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, given the higher costs associated to the alternative one, while other emerging economies from 2045 would gain from the GCF-alt Scenario, given the higher costs associated to GCF-neg in the long run. 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.

**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* |

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.[63] 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[64], its higher competitiveness on global markets prejudice other economies, especially those which play a role in international markets.

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

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, registers a sharp welfare reduction in the GCF-neg Scenario. This is 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).[65] 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.

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

| **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 |

It is then clear that, as already stated in the previous qualitative analysis, 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

[65] See Tables 9 and 10.

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. Today, the GET-550 seems to be the favourite Scenario at global level, as well as the GCF-neg once the GCF is introduced.

**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 |

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. Accordingly, 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. In 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 |

## Conclusions

The main purpose of this research has been to investigate how the role of developing countries in the fight against climate change has been changing over time. By looking at the three papers in which this work is divided, it emerges how, despite several attempts being made in recent years, the lack of cooperation between developed and developing countries constitutes one of the main shortcomings characterizing both the Kyoto Protocol and climate negotiations.

As for the Kyoto Protocol, this scarce cooperation has compromised the success of the only instrument involving developing countries, the Clean Development Mechanism. It was specifically created to achieve both a reduction in mitigation costs and to stimulate a sustainable development path in developing countries. Nevertheless, investing countries implement CDM projects only in a few emerging economies, namely China, India and Brazil, and thus substantially ignore the role of CDM in promoting sustainable development in least developed countries. As argued in the first paper, cost effectiveness in abatement efforts is not the main driving force influencing the decision on destination markets. By applying a gravity model to a panel dataset, well-established export flows from developed economies towards developing countries are shown to explain a large portion of the geographical distribution of CDM projects. Thus, a new climate regime and an ad hoc policy action are required to redistribute CDM projects towards developing countries. Nevertheless, at the end of the first commitment period in 2012, Parties failed in reaching a new agreement and the Kyoto Protocol was extended until 2020 with the intent to carry on negotiations in the meanwhile.

During Post 2012 negotiations, greater attention was devoted to the interests of developing countries, resulting in several decisions concerning both adaptation and mitigation (NAMAs, NAPs, Green Climate Fund, Technology Transfer Mechanism). However, the lack of cooperation between developed and developing countries has influenced also Post Kyoto negotiations, characterized by a deep deadlock. Indeed, the growing role of developing countries in global emissions has exacerbated the debate about the CBDR principle, preventing Parties to reach an agreement on the future burden sharing. A related argument behind the deadlock has been the emergence in climate negotiations of more differentiated positions compared with the traditional segmentation between developed and developing countries. As it turned out to be evident in last COPs and as confirmed by the cluster analysis conducted in the second paper, developing countries have different expectations and concerns about climate change negotiations, reflecting huge differences with respect to their economic, political and human conditions. Consequently, the relative position toward mitigation vs. adaptation support and with respect to the stringency level of future mitigation pathways is highly dependent on the structural features that characterize single countries. Given this high heterogeneity and in order to maximize the likelihood of a successful climate agreement, it is necessary to design differentiated supporting actions according to countries' specific interests and weaknesses.

Last December, during COP 21 held in Paris, Parties finally succeeded in reaching an International Agreement to be implemented in 2020. Although it is a timid step forward towards a burden sharing involving all countries, cooperation issues are still undeniable, especially concerning the interpretation of the CBDR principle. As a result, the Paris Agreement is still too weak, based on a voluntary approach and characterized by the absence of sanctions for non-compliant countries. Despite the growing need for an active participation of developing countries in mitigation actions, it is still true that they are the most affected by climate change. As argued in the third paper, developing countries, especially the poorest ones, are in fact suffering the highest costs, with a GDP loss higher than 16% in 2050. A key role is then played by the GCF, that can act as a compensating mechanism reducing the gap between costs and benefits of mitigation policies and vulnerability to climate change. Nevertheless, setting up an effective resource allocation method is one of the most demanding issues. Climate change policies affect many aspects of a country's economy, such as welfare and GDP. Shifting from a policy evaluation criterion to another can lead to several and often contrasting conclusions. Moreover, the preference of a country for an allocation method is strongly influenced by its characteristics and needs. The heterogeneity of developing countries makes this goal even more challenging.

To conclude, the main results arising from this research have highlighted the growing role of developing countries over time as well as the challenges the world must face to overcome the lack of cooperation between developed and developing countries in order to reach an effective climate agreement. In view of this, the main policy advise arising from this research is to design a well structured country-specific GCF. This would contribute to persuade developing countries to actively participate in mitigation policies as well as to facilitate negotiation processes. Indeed, 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.