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DIPARTIMENTO DI ECONOMIA

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Do bilateral commercial relationships influence the distribution of CDM projects?

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Abstract

This paper contributes to the issue of the uneven distribution of Clean Development Mechanism (CDM) projects among developing countries. By applying a gravity model to a panel dataset at bilateral country level, we find that well-established export flows from developed economies towards developing countries explain a large portion of the geographical distribution of CDM projects. The policy implication we derive is that a sort of lock-in effect in the CDM relationship should be avoided by enhancing the institutional framework in developing countries hosting CDMs as well as by reinforcing compulsory rules for CDM destination toward the least developed economies. On the contrary, if market forces are left free to influence CDM destination, cost effectiveness in abatement efforts is not the driving force influencing the decision on destination market, but other criteria based on private benefits seem to prevail.

Keywords: Kyoto Protocol; Clean Development Mechanism, Export Flows; Gravity Model; Institutional Quality

J.E.L. codes: F140; F180; Q540; Q560

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1. Introduction

Climate change is recognised as one of the greatest environmental, social and economic threats facing the world. Global warming 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 parties, broadly corresponding to industrialised and developing countries. Moreover, 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).

As the first commitment period (2008-2012) is finished yet, parties are discussing what will be the future of the KP. 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) which aims to help developing countries cope with climate change by fostering the diffusion of clean technologies in particular. However, the most important agreement reached during the COP 17 is the deal called the "Durban Platform for Enhanced Action" where Parties agreed on the extension of the KP for a second commitment period (although some countries such as Canada, Japan and Russia did not sign it). Meanwhile, Parties will negotiate for the creation of a new international treaty by 2015 so that it will be operational by 2020. The most important aspect of this new treaty is that it must require 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. In a nutshell, the CDM allows a country with an emission-reduction commitment to implement an abatement project in developing countries. Such projects can earn certified emission reduction (CER) credits, each equivalent to one ton of CO_2-eq, which can be used by industrialised countries to meet their emission reduction targets under the KP, or can be banked for future commitments or alternatively traded in 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).

Nevertheless, the distribution of CDM projects has been very unequal so far: about 70% of registered CDM projects have only been implemented in three countries, Brazil, China, and India whereas only 1.6% of projects have been 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, leaving out 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.

Although the unequal distribution of projects represents one of the major shortcomings of the CDM, so far most of literature has focused on the ability of CDM projects to create sustainable development in host countries, the capacity to reduce abatement costs in investing countries and the real technology transfer effect from rich countries towards 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.[2] 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 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 the CDM that, with the participation of communities in the implementation of CDM projects, allows local capacity to be enhanced by starting a process of learning by doing that can lead to higher levels of know-how and education as well as the creation of employment. In this way, projects can contribute to a structural change in terms of innovative

[2] 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)).

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), in the context of the CDM, technology transfer also plays another role: it can be considered an incentive for cost-effective emission reductions under bilateral CDM contracts when there is asymmetric information between the investor and the host party. In other words, it represents a motivation that counterbalances any incentives to cheat on emission reductions. In the absence of technology transfer, the host country (agent) would have incentives to exaggerate the emission reduction costs in order to receive a higher compensatory transfer payment,[3] whereas, with the technology transfer included, overstating this cost means that the value of the technology for the developing country is emphasised and the agent's original incentives not to reveal the actual costs are partially counterbalanced.

Among 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 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 also an effect on absorptive capacity for host countries so that 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).[4]

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. In fact, so far, only a few of the existing contributions have analysed the causes

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

[4] 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.

behind this phenomenon.

According to Jung (2005), for example, there are three factors that can explain the attractiveness of host 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. The country must also indicate the development priorities that Annex I countries have to take into account in their projects and not all developing countries have the experience and the institutional capacity to satisfy these prerequisites.

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 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. Nonetheless, the level of international trade is considered unilaterally from the host country's point of view whereas trade-related bilateral relationships are completely ignored.

In order to fill this gap, in this study we explicitly model the role of trade bilateral relationships by modelling a gravity equation where export flows from each investor to each host country are accounted for among the explanatory variables. More specifically, our 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.

We also test two ancillary research questions. We argue that, 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.

We also consider 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.

The rest of the paper is organised as follows. Section 2 provides a description of some stylised facts concerning the implementation and distribution of CDM projects. Section 3 describes the dataset and the empirical methodology we used in our analysis. In Section 4 we discuss the empirical results from econometric estimations and Section 5 provides some concluding remarks.

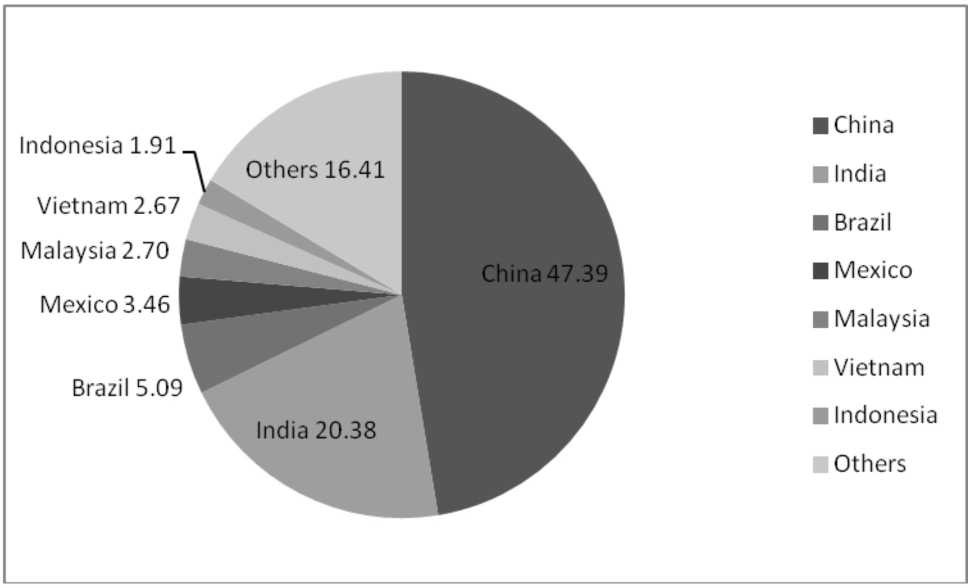
2. Stylised facts: implementation and distribution of CDM projects

In order to provide descriptive statistics of the distribution of CDM projects, we have considered official information provided by the UNFCCC and the CDM Pipeline in the time span 2005-2011. These data give us information on the number of projects implemented (by host country and investor), as well as the amount of investments and issued CERs by host country.

As of 31 December 2011, projects have only been implemented in 73 developing countries and many of these countries host just one project. Figure 1 shows the distribution of registered projects between countries. As previously stated, China hosts almost half of the projects whereas no least developed countries (LDCs) are represented. In fact only 4.6% of the projects have been implemented in LDCs as an aggregate.

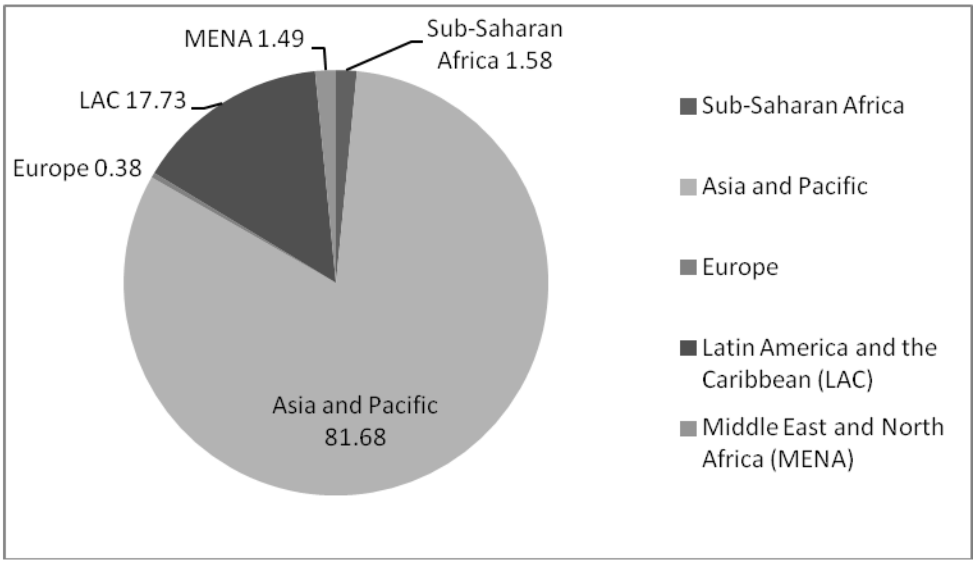
Even if we look at regional distribution, we can see how it is unequal: most CDM projects, in fact, are implemented in Asia whereas Sub-Saharan Africa, where most of the LDCs are concentrated, hosts only 1.58 % of projects (Figure 2).

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



Source: Our elaboration on UNFCCC (2012)

Figure 2 – Regional distribution (% of total projects as of 31 December 2011)

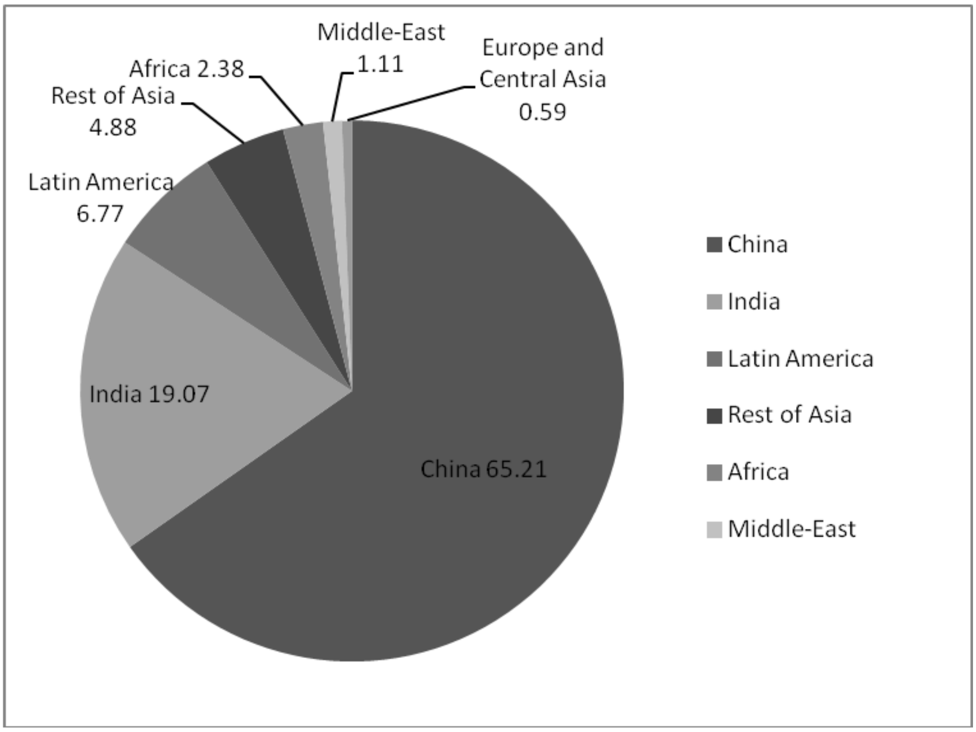


Source: Our elaboration on UNFCCC (2012)

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 giving a development opportunity to all countries that lag behind is far from being achieved.

Even if we look at the monetary efforts in CDM of about 188 billion US$ until 2011, we can see that most of it (65%) has been invested in China (Figure 3).

Figure 3 - Destination of CDM investments (%of total investments as of 31 December 2011)



Source: our elaboration on UNEP (2012).

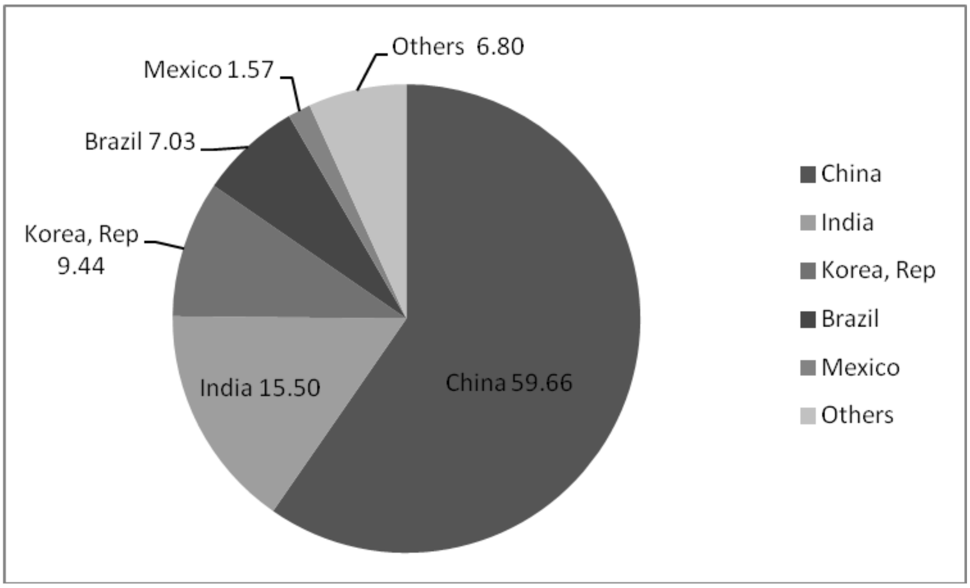
If we compare results in Figures 1 and 3, we can see that CDM investment flows in China have been even larger than the number of projects. This means that there is a great concentration of large size projects in China.

Moreover, we can see that the number of CERs issued by the host party reflects the distribution of projects, as illustrated in Figure 4. If we compare Figures 1 and 4, 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 CO_2-eq, this means that so far about 877 Mt CO_2-eq. have been abated through CDM projects.

Finally, we can see that, although it is true that CDM projects mostly follow the emission reduction objective but 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.[5]

Figure 4 - CERs issued by host party (up to 31 December 2011)



Source: our elaboration on IGES (2012).

If we compare Ranking (1) with Ranking (3), we can see that host countries corresponding to the top ranks are not those with the highest efficiency (except for Brazil). The best example is that of 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. The same can be observed for India which loses six positions. On the other hand, there are countries such as the Republic of Korea and Argentina, that do not attract many investments although they register a high level of efficiency (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, but these data suggest that there must be other factors that influence the distribution of projects that keep on going towards emerging economies, leaving out other

[5] 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.

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 (mln US$) (1)	CERs (tons of CO2-eq) (2)	Investment efficiency (ton of CO_2 per mln US$) (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

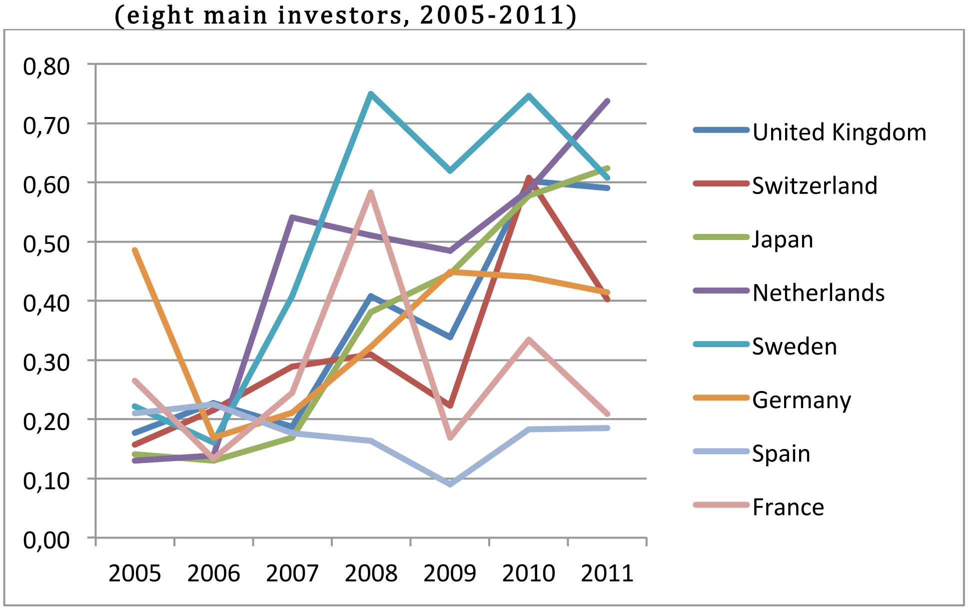
Source: our elaboration on IGES (2012) and UNEP (2012).

By looking at main investors, exactly the opposite has occurred since final destination concentration has increased over time for almost all considered countries. For this reason, we selected as an example the largest investors (namely the United Kingdom, Switzerland, Japan, the Netherlands, Sweden, Germany, Spain, France) representing about 90% of total CDM projects over the whole period 2005-2011 and we computed an Herfindahl concentration index for each investing country (H_{it}) in the form:

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

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, we considered 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 5 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.[6]

Figure 5 – Trend in Herfindahl concentration index of CDM projects for destination countries (eight main investors, 2005-2011)



Source: our elaboration on UNFCCC (2012)

By looking at Figure 6, 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, a quite clear positive correlation emerges 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

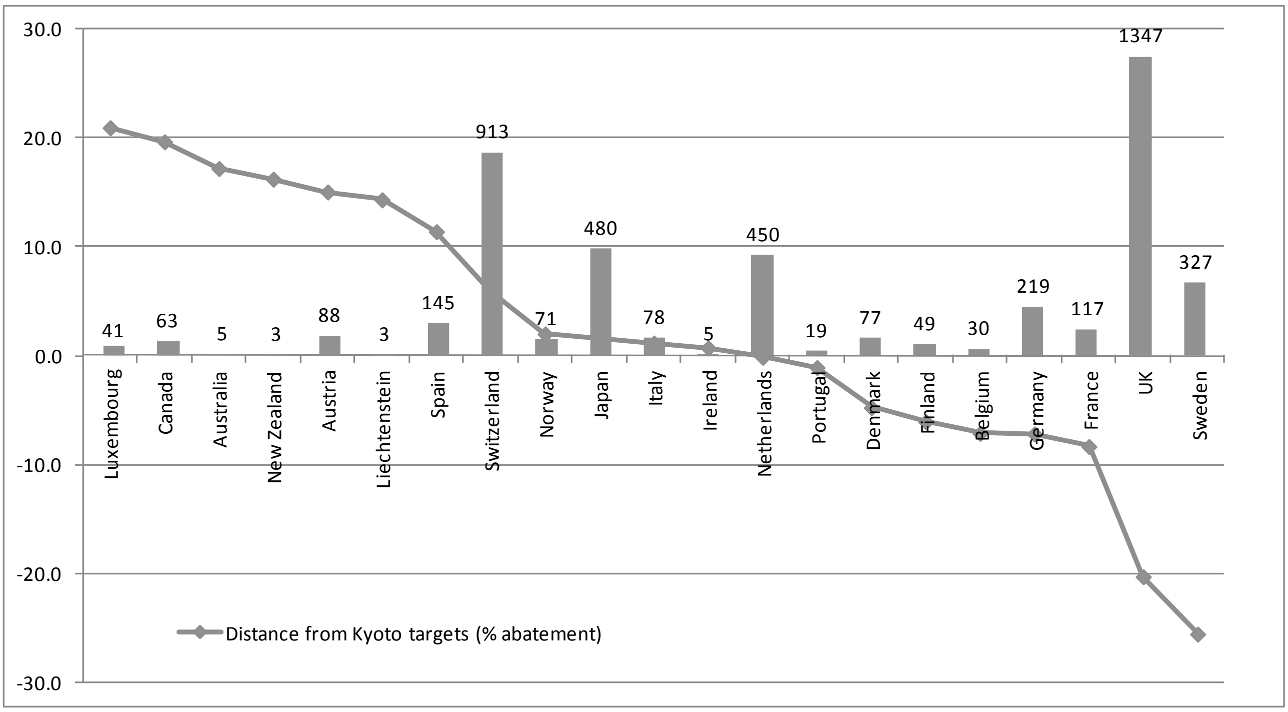
[6] By looking at distinguished host countries for the four top investors (namely the United Kingdom, Switzerland, Japan and the Netherlands), it is also worth noting that the largest concentration is given by increasing projects directed towards China, with a clear crowding out effect compared with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

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 here represented by figures on the top of grey bars, and their distance from Kyoto targets as represented by the grey line. 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.

Figure 6 - 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: Our elaboration on UNFCCC (2011, 2012).

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 leads us to reinforce 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). To the best of our knowledge, 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, α_{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:

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

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 our research hypothesis, our empirical model differs from Wang and Firestone (2010) in several ways. First of all, our 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 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, we explicitly model the role of already existing commercial relationships by investigating the role of bilateral trade as a consolidated channel of international exchange that also facilitates CDM investment decisions. Third, we also shape the role of institutional quality 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 investing behaviours.

Furthermore, 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, we 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.

Our 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 we present 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, we expect β_1 to be negative and β_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.[7] We then introduce a set of explanatory variables representing the role of mass for i and j countries here modelled with a one year lag for excluding potential endogeneity bias ($ln\boldsymbol{M}_{i,t-p}$ and $ln\boldsymbol{M}_{j,t-p}$). In this case, we tested several measures of mass since there are no decisive empirical findings on this issue. In particular, the economic size of reporters and partners was modelled by using GDP per capita at purchasing power parity available from the World Development Indicators (WDI) online database (World Bank, 2012).[8] As we have already stated, the number of projects and the investment dimension are strongly influenced by MACs. Here we shaped this issue by including country specific CO_2 emissions level for i and j countries, here taken as the sum of all GHG emissions expressed in CO_2 equivalent terms provided by WDI. It is clear that in this empirical framework, we expect both β_3 and β_4 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, again the higher the level of total CO_2 emissions, the wider the range of available abatement possibilities or, in other words, the lower the MAC. In order to gather information on the role of the energy system, we controlled for the role of electricity production as well as the level of electricity produced by renewable sources. Recalling main findings in trade-based gravity model, the mass plays a role as a demand driver. This means that in both cases - by using GDP per capita or total electricity production - we expect β_3 and β_4 to assume a positive sign. The larger the economic or energy system, *ceteris paribus*, the higher the demand for a wide range of abatement tools in order to be compliant with emission targets. With regard to electricity

[7] We also controlled for the role of past colonial relationships but it is not a robust regressor. Results are available upon request from the authors.
[8] A complete description of all variables is available in the Appendix, Tables A1 and A2.

production by renewable sources, a theoretically based sign is only valid for the investing country in our opinion. Bearing in mind that CERs may be banked and then sold into the carbon market, we modelled the gravity equation 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 exploiting renewable technologies in order to gain from accumulating CERs and selling them into the carbon market. When modelling the energy system, we also used WDI data source.

In order to answer our main research question, in our estimations we tested the role of bilateral trade relationships ($\ln T_{ij,t-p}$), 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 methods, as a common choice in trade literature, especially for bilateral relationships, we computed a two-year average value for each export flow. 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, since several concerns have arisen in recent years related to severe constraints given by a weak institutional setting of hosting countries, we also controlled for the quality of institutions of both investing and hosting countries, 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 certificating emissions reduction in host countries, since in Non-Annex countries emissions registry is not compulsory, and the low quality of rules for respecting legal aspects of contracts and agreements, have been recognised as important concerns at theoretical level 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 β_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, we selected two indicators, namely Law and Order (LO) and Investment Profile (IP). The first one consists of one of the most widely used institutional quality indices whereas IP, in our opinion, represents the most closely related measurement with respect to the object of our 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 our analysis, we normalised these values to a common 12 maximum value.

Finally, we included controls for two specific issues. 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 abroad. Our expectations are that for both i and j countries β_8 and β_9 are negative, with a greater emphasis on investing countries. The second issue relates to the level of involvement in international negotiations for climate change. According to the role played by different countries in COPs, we might well expect, *ceteris paribus*, European Union (EU) countries to be those showing the largest propensity to invest in CDM projects in the analysed period since they represent the bargaining bloc 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, we expect these countries to show a relative higher propensity to invest in CDM in order to reduce abatement costs, but also to be first comers in this new market. For this reason, we modelled a dummy variable (dEU_i) assuming value 1 if the investing countries is an EU member, and 0 otherwise.

The 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) whereas j host countries ($\forall j \in (1, N), with\ N = 126$) are all the potentially receiving countries as available from the UNFCCC website, during the period from 1 January 2005 until 31 December 2011.[9] The total number of potential observations is thus given by $Obs. = M\text{x}N\text{x}T = 17{,}640$.

As a matter of fact, since we carried out a panel estimation, 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 induce statistical problems to be solved. Recent advancements in the econometric estimation of a gravity model provide useful suggestions in this direction. 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 is due to neglecting the impact of firm heterogeneity in the decision on how much volume to export

[9] 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, 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.

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 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 our case, the discrete nature of our 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 our framework of 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 speaking, the PRM assumes that the dependent variable has a Poisson distribution, denoted by $y \sim Poisson(\mu)$ where μ 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).[10]

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. ν, that generates additional variability in the outcome, so that $y \sim \text{Poisson}(\mu\nu)$. Given that our dependent variable is strongly overdispersed, a fixed effects NBRM model is used to estimate eq. (4).[11] The maximum likelihood method is used to estimate the model

[10] 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. For a specific reference to gravity model see Burger *et al*. (2009).

[11] 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.

parameters.[12]

Finally, in order to account for unobservable country-pair specific heterogeneity (α_{ij}), we rely on the fixed effects estimator by conditioning the probability of the counts for each group on the sum of the counts for the group.[13] According to recent findings in gravity model estimation for panel dataset, time variant fixed effect for reporters and partners should also be included (Baldwin and Taglioni, 2006). Hence, we have included time-variant country effects for *i* and *j* as expressed by $\gamma_{i,t}$ and $\delta_{j,t}$.[14]

4. Empirical results

In order to answer our research questions, the analysis was divided into two stages. In the first stage, we investigated the role played by the variables representing the economic and energy structure as drivers of the implementation of CDM projects. In the second stage, we introduced regressors representing the role of commercial bilateral relationships and the quality of institutions to 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), we considered additional estimations in which the economic aspect is analysed together with three alternative environmental variables, namely CO_2-eq emissions, electricity production and electricity production from renewable sources (M3, M4, M5). It is worth noting that all coefficients for these variables are positive and statistically robust for both investors and host developing 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

[12] The maximum likelihood negative binomial mean-dispersion estimator is not consistent if the variance specification is incorrect. As an alternative estimation strategy we have estimated our basic equation 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, we have also estimated models 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. All results based on pseudo maximum likelihood approach and the GMM are available upon request from the authors.

[13] 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.

[14] 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 our case all dummy variables) represent semi-elasticities.

considered a key driver for directing investments in CDM projects.[15] According to the general empirical setting described in eq. (4), we tested several lag structures in order to reduce potential endogeneity while obtaining robust results. The optimal lag structure appears to be *p*=1, but for lag values higher than 1 results remain quite robust and stable.

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)
CO_2 emissions $_{i\ (t-1)}$		0.09	0.69***		
		(1.08)	(5.65)		
CO_2 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
χ^2	313	253	368	387	374

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

An interesting point concerns the role played by renewable energies. According to our expectations, the higher the installed capacity of renewable energy production, *ceteris paribus*, the higher the probability that one *i-th* Annex I country will be a large investor in

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

CDM, as well as the larger the renewables in host countries, the higher the propensity to absorb CDM projects.

Since potential multicollinearity bias may arise from considering economic and energy variables simultaneously, we controlled for correlation values between GDP per capita and alternatively CO_2 emissions and all other energy-related variables. All correlation values are below 0.30. As a further robustness check, we also checked for multicollinearity bias 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 mean VIFs for the whole regressions are always below 2. For condition numbers, the condition of statistics below 50.00 is always respected.[16]

Moreover, we can see how 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 our 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.

Let us now introduce further explanatory variables, representing the core of our study, in a second set of econometric specifications (Table 3). In particular, we enriched the last three regressions of Table 2 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).

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 to the analysis makes the other variables significant for developed countries only unlike that shown in Table 2 and reported in previous studies.[17]

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 seems to play a large role in influencing the distribution of CDM projects.

[16] For the sake of simplicity, we do not report statistics in Tables, but they are available upon request from the authors.
[17] Wang and Firestone (2010); Winkelman and Moore (2011).

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
χ^2	384	399	407	378	395	399

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

This is also true in the second group of regressions when the institutional variable is introduced. With regard to this issue, it is worth noting that LO is positive and significant for host countries and 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 for investing countries located in the European Union (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 parties.

Finally, we built a third set of econometric specifications in order to control for robustness (Table 4). As in the previous step, we conducted the analysis by revising the last three regressions of Table 2 (with GDP per capita and the three environmental variables). In this case, in a first stage, we proceeded by 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 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 even if the export flows is not included in the regression.

We then replaced LO 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, we simultaneously analysed IP and the trade-related dimension (M7-M9). Even in 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) which is comparable with those obtained with LO.[18]

[18] 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

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)
Export flows $_{ij\,(t-1)}$							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
χ^2	369	389	413	345	400	379	350	403	406

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

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, we have also developed an econometric estimation of models M4-M6 in Table 3 and M7-M9 in Table 4 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. For the sake of simplicity, results are not included here, but they are available upon request from the authors.

Broadly speaking, given the fact that gravity models account for several dimensions of bilateral relationships, our 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 us 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 last clear empirical finding refers to the reduced role played by MACs when accounting for IP (M7-M9). The large impact of investment profile in Annex I countries strongly reduces the explanatory power of all energy-related regressors, where MAC coefficients, above all, in both investors and host countries are no longer statistically robust.

The only driver of investment decisions still maintaining its role is represented by renewable electricity production in investing countries. This result can be interpreted as a sign of the positive role played by domestic institutions where investment profile 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 *et al.*, 2012). 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.

By describing the location of CDM projects at geographical level, it is clear that investing countries implement CDM projects only in a few emerging countries, namely China, India and Brazil, thus substantially ignoring the role of CDM in promoting sustainable development in least developed economies.

According to the descriptive picture of such uneven distribution, in this paper we have mainly emphasised the role played by already existing bilateral commercial relationships as a potential driver for investment decisions. Econometric results show that cost effectiveness in abatement efforts criterion is not the only driving force influencing the decision on destination markets. Bilateral export flows from Annex I economies toward Non-Annex 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. In addition, our results also allow us to quantify the role played by the institutional setting in investing countries. When the overall investment profile of reporters and partners is included, it should be stressed that the Annex I countries with better investment environment correspond to those countries with the highest propensity to invest in CDM.

The second ancillary condition related to the role played by the installed capacity to produce renewable energy is also confirmed by empirical results. This means that the countries with higher renewable energy production correspond to the players in the international scene with larger competitive advantages to investing in CDM.

The first policy implication we can derive from these results is that in order to overcome this sort of lock-in effect in CDM investment distribution, an ad hoc policy action is required to redistribute CDM investments in developing countries. A first reply to this requirement is represented by carbon funds managed by the World Bank, but 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 second policy implication deriving from our study is represented by the need for an enhancement of the institutional framework in developing countries hosting CDMs, as a major factor in reducing transaction costs and the risk of uncertainty and thus providing a stable environment for investment decisions.

These policy implications are very important, especially at this time, because of the relevance they have in the context of the negotiations that are taking place concerning the future of the Kyoto Protocol and its mechanisms, as well as, more generally, the fight against climate change and its impacts on developing countries.

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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 flows$_{ij}$ ($lnT_{ij,t-1}$)	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 flows $_{ij}$	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

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