Central America in the emissions market: a multi-criteria assessment of clean development mechanism projects

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Abstract

This study evaluates Central American countries' participation in the Clean Development Mechanism (CDM), which was instituted by the Kyoto Protocol to mitigate greenhouse gas (GHG) emissions. The authors examine whether this mechanism promotes sustainable development in host countries, whose economies are relatively small. Simultaneously, the authors conduct a multi-criteria evaluation of large- scale CDM projects in Central America. Findings show that the mechanism advances host countries' current priorities, rather than promoting sustainable development, thereby failing to meet one of the objectives of the CDM. Economic progress is a high priority at the local level and, accordingly, economic benefits outweigh social benefits, with local environmental costs being incurred in the process.

Keywords: greenhouse gas emissions; environmental impact; sustainable development; investments; multi-criteria analysis; Clean Development Mechanism.

1. INTRODUCTION

This article examines several Central American countries' experience with investments related to the Clean Development Mechanism (CDM), an instrument instituted in 2008 by the Kyoto Protocol to address global greenhouse gas (GHG) emissions.[1]

The CDM is an alternative method for developed countries to achieve certified emission reductions at below market price, and at the same time is an opportunity for developing countries to attract investment. Despite the centrality of global environmental concerns, however, several studies have observed that CDM projects have been motivated by economic concerns, in particular, by financial concerns (see Karakosta *et al*., 2009; Anagnostopoulos *et al*., 2004). On the one hand, developed countries are incentivized by the low-cost certified emission reductions, while on the other hand, developing countries are encouraged to participate in the mechanism by the low-cost financing and technology transfer.

In this sense, the CDM contributes to the global objective of reducing emissions. However, it does not directly address the host country's (long-term) sustainability needs, but rather its local priorities in the short- and medium-term. This is the case for several African, Asian, and Latin American countries (Karakosta *et al*., 2009). CDM negotiations need to maximize potential spillovers to promote sustainable development in host countries, yet the majority of such deals have failed to meaningfully address these externalities (see Burian and Arens, 2014; Karakosta *et al*., 2009). In other words, as identified by Sutter and Parreño (2007) in their analysis of 16 CDM projects, this mechanism has not addressed one of Kyoto Protocol's two stated objectives, namely, to promote sustainable development in the host country. At the time of writing, there is no research published on the impact of these measures on developing economies. In light of this, it is hoped that an assessment of the Central American experience will go some way to addressing this gap in the literature.

To this end, the present article analyzes whether CDM projects do indeed achieve the objective of promoting sustainable development in Central American countries. Here, it is particularly pertinent to ascertain whether there has been a negative environmental impact in the region, determined according to a scale effect of the specific projects evaluated. Equally crucial is determining whether the disparities in the net benefits (where costs have been discounted) of the CDM between host countries are related to their socio-economic and environmental differences. Finally, this paper assesses whether host governments have learned to negotiate and manage CDM projects and achieve greater local social and economic benefits over time.

In light of these dual objectives, a CDM project should be centered on two considerations: the global abatement of GHG emissions and the host country's development. An effective evaluation of such a project should, therefore, examine not only a project's global impact on emission reductions, as is commonly done, but also the impact on local development, from economic, social, technological, institutional, and environmental perspectives. The present study factors in these local effects, thus necessitating a multi-criteria analysis.[2]

This paper consists of an introduction and four other sections. Section two Illustrates the context and the main characteristics of the projects evaluated, while section three explains how a multi-criteria analysis is applied to the study projects. Findings are then discussed in section four, with some conclusions offered in the final section.

2. CDM IN CENTRAL AMERICA CONTEXTUAL CONSIDERATIONS

The seven countries that make up the Central American region (Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama) have small, developing economies and low GHG emission levels. In fact, according to World Bank data (2019), in 2016, the sum of the countries' Gross

Domestic Product (GDP) was equivalent to 1.3% of the GDP of the United States, 7.0% of Germany's, and 4.5% of Latin America and the Caribbean's. In the same year, the group's per capita GDP averaged 11% of that of the United States, 15% of Germany's, and 72% of Latin America and the Caribbean's. Furthermore, according to figures from the Economic Commission for Latin America and the Caribbean (ECLAC, 2019), for 2014, emissions from Central America were equivalent to 4% of the total for Latin America and the Caribbean. There is a degree of correspondence between the size of the economy and GHG emissions for this group of countries, although this is not as linear as the World Bank (2019) and ECLAC (2019) statistics suggest. Thus, on the one hand, two of the three largest Central American economies in the group are among its three main GHG emitters. However, Guatemala, the largest economy, is not the main emitter, and instead occupies second place. On the other hand, the largest emitter is Honduras, whose economy is the fifth-largest (its GDP is equivalent to 20% of Guatemala's GDP). There are significant disparities within the group, such as in per capita GDP, suggesting development gaps between countries. For example, Nicaragua's and Honduras' GDP per capita was 14.7% and 16.2% of Panama's in 2016, respectively (World Bank 2019).

Under these circumstances, governments in the region have sought to develop not only economically, but also in the social and energy spheres. The political agenda, however, has prioritized the economic aspect. In terms of energy production, they have tried to diversify their energy matrix via increased use of renewable energy sources.

In 2012, the year which marks the end of the first Kyoto Protocol commitment period, Central American electricity production was 44,282 gigawatt-hours (GWh), of which 50% was generated in hydraulic power plants; 31% in thermal power plants; 8% in geothermal power plants; 3.9% in sugar plants; 4.4% in coal-fired power plants; 2.7% in wind power plants; and 0.05% in biodigesters and solar parks. In this context, Costa Rica produced 91.8% of its electricity via renewable sources; Guatemala 65.4%; Panama 64%; El Salvador 59.5%; Honduras 44.1%; and Nicaragua 40.2% (ECLAC, 2013). The hydroelectric projects these nations have registered in the CDM have been selected for analysis due to their importance at the regional level.

Between 2003 and 2012, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama registered 103 energy production projects in the CDM; 49 of them were hydroelectric projects, 18 gas capture projects, 15 wind projects, 4 geothermal projects, 6 cogeneration projects, and 11 other small projects of different types (United Nations Framework Convention on Climate Change [UNFCCC], 2015). The hydroelectric power plants, besides accounting for the largest share of electricity generation, also achieved the largest emissions abatement via the CDM, totaling 2,946,905 tons of CO_2e, with significant economic, social, and environmental impacts on the areas in which they were implemented.

As illustrated in table 1, the large-scale CDM projects registered between 2003 and 2012 were implemented in an institutional context during a period with three particularly salient characteristics: 1) governments in the five host countries were motivated by economic concerns; 2) in terms of legislative reform actions, only Guatemala's government implemented legislation for managing the CDM. This legislation was recently reformed to incorporate sustainable development and climate change issues, at which time, the governments of El Salvador, Honduras, and Panama carried out legislative reforms on energy generation from renewable sources and to attract foreign investment in these activities; 3) in all host countries, there were challenges to implementing and enforcing CDM projects. Host countries experienced social conflicts and legal claims for damage caused to surrounding communities and the natural environment resulting from projects' construction and start-up phases. (see Molina-Rodríguez, 2019, chapter III).

Table 1. Three features of host government behavior in registering and implementing large-scale CDM projects, 2003-2012a[a]

Action	*Costa Rica*	*El Salvador*	*Guatemala*	*Honduras*	*Panama*
Main motivation was financial	Yes	Yes	Yes	Yes	Yes
Implemented legislation with reforms that included topics on sustainable development and climate change	No	No	Yes	No	No
Made legislative reforms to attract foreign investment in the energy industry	No	Yes	No	Yes	Yes

Notes: [a] Belize and Nicaragua did not register any large-scale projects.

Source: Compiled by the authors, based on Molina-Rodríguez (2019, chapter III).

The selected projects

As previously mentioned, out of a total of 49 hydroelectric plants present in the region at the end of 2012, 17 were large-scale (installed capacity greater than 15 megawatts [MW] per plant). These had been negotiated as part of the CDM with the commitment that foreign companies would reduce 2,262,844 tons of CO_2e emissions per year in their places of origin, corresponding to one CER for each ton of reduction (that is, a total of 2,262,844 certificates), which is equivalent to 77% of the total number of certificates issued in the Central American region (see UNFCCC, 2015). The host countries of these projects were: Costa Rica, El Salvador, Guatemala, Honduras, and Panama. Two other countries, Nicaragua and Belize, did not register large-scale CDM projects. The five participating countries' offers of CER attracted foreign companies, which offered financing and technology, in addition to purchasing these certificates.

Most of the 17 selected projects were located on riverbanks in areas with low levels of development. Projects' installed capacity ranged from 20 to 118 MW, revealing a wide range of project sizes. Facilities also had diverse ages ranging from the beginning of 2003 to 2012 (the year the present study is based on). The concession terms also cover a range, although not as wide, from 17 to 50 years (see Appendix 1).

There is a range of country participation in the CDM, as well as notable differences between projects (see table 2). It can be seen that Panama, Guatemala, and Costa Rica are the countries that register the highest participation with these projects (Panama with six projects, Guatemala with five, and Costa Rica with four). El Salvador and Honduras registered only one project each. The rate of GHG emissions reduction associated with the projects, for each MW of their capacity, is between 1,267 and 2,873 tons of CO2e per year. It can also be seen that the execution of the projects was awarded to private companies, with the exception of El Salvador, where the executing entity was state-owned.

Table 2. Summary of the 17 hydropower projects studied (2012 data)

Country	*Number of projects*	*Installed capacity (MW)*	*Annual emissions reduction (Tons of CO2e)*	*Reduction rate of emissions by capacity (Tons of CO2e / MW)*	*Executing entities*
Costa Rica	4	190	251 495	1 324	Private
El Salvador	1	65	144 091	2 217	State-owned
Guatemala	5	291	830 882	2 855	Private
Honduras	1	38	109 168	2 873	Private
Panama	6	368	971 754	2 641	Private
Total	17	952	2 307 390	2 424	

Source: UNFCCC (2020).

3. GUIDELINES FOR THE MULTI-CRITERIA ANALYSIS

Once the projects were selected, analysis began with data being organized in order to calculate each project's net benefits (with costs discounted). Two parallel processes were conducted according to the guidelines of two methods of multi-criteria analysis: the Analytic Hierarchy Process (AHP)[3] and a variant of Simple Additive Weighting, respectively.[4] Based on these analyses, criteria were established at two levels, the data was standardized, and each project's net benefit was then calculated.

Criteria

The projects were evaluated according to two scenarios with different primary objectives. Although the same criteria and categories were used to evaluate each scenario, the benefit function is defined differently in each case. We expand on this later. In both cases, following the AHP guidelines, the criteria were initially prioritized on two levels. Three first-level criteria: Environmental (A), economic (E), and social (S).

$$A + E + S = B \qquad (1)$$

where *B* is the net multi-criteria benefit (gross benefits minus gross costs).

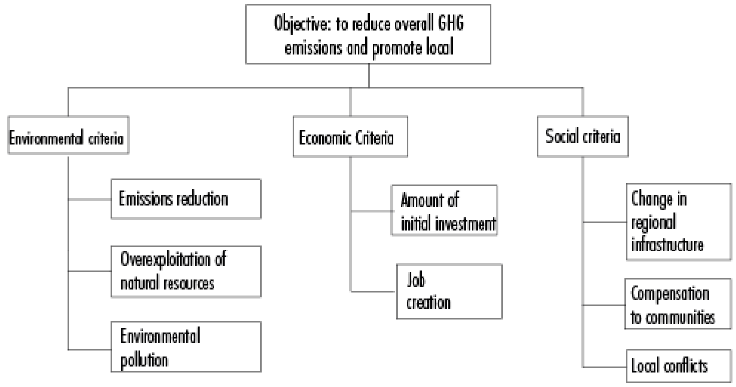
Subsequently, three second-level criteria were assigned to the environment: annual reduction of GHG emissions (a_1), overexploitation of natural resources (a_2), and degradation by change in the use of the natural environment (soil, water bodies, etc.) (a_3). These criteria were decided based on the availability of data.

The second level economic criteria are: *a*) amount of initial investment (e_1), and *b*) job creation (e_2). Finally, the social criteria include the following second level criteria: *a*) changes in regional infrastructure (s_1), and *b*) compensation.

Normalization

The main data source for the study is the series of "Project Design Documents" for the 17 hydropower plants (see UNFCCC, 2019). Interviews were also conducted with officials from each country. Since this data is heterogeneous (monetary figures, percentages, engineering or biological data, qualitative data, etc.), it was normalized as usual in the application of AHP and Simple Additive Weighting methods. The procedure is illustrated in figure 1 with a tree of the multi-criteria analysis, starting from the primary objective, and including the criteria on the two levels and the signs referring to benefits and costs. Table 3 provides a summary of this data and incorporates the values and the manner in which they are assigned.

Figure 1. Multi-criteria tree to evaluate the 17 CDM projects



Source: Compiled by the authors, applying AHP criteria and Simple Additive Weighting to data from UNCCC (2019) and interviews with officials from the study countries.

Table 3. Composition and characteristics of the criteria

Key	*Description*	*Original unit of measurement*	*Benefit (+) or cost (-)*	*Categories to normalize*			
Environmental criteria							
a1	Emissions reductions	%	(+)	Interpolation (from 0 to 1)			
a2	Overexploitation of natural resources	Quantitative and qualitative	(-)	High (-1.00)	Average (-0.67)	Low (-0.33)	Null (0)
a3	Environmental pollution	Quantitative and qualitative	(-)	High (-1.00)	Average (-0.67)	Low (-0.33)	Null (0)
Economic criteria							
e1	Amount of initial investment	Monetary value	(+)	Interpolation (from 0 to 1)			
e2	Job creation	Number of employees	(+)	Interpolation (from 0 to 1)			
Social criteria							
s1	Change in Regional infrastructure	Quantitative and qualitative	(+), (-)	Damage (-1)	No change (0)		Improvement (1)
s2	Compensation to communities	Quantitative and qualitative	(+)	No (0)		Yes (1)	
s3	Local conflicts	Quantitative and qualitative	(-)	Yes (-1)		No (0)	

Source: compiled by the authors

a) Environmental criteria

The second level environmental criterion of GHG emissions reduction is analyzed using data originally in tons of CO2 emissions per year. These data pertained to the baseline annual emissions in percentage terms. As shown in table 3, 1 point was given to the maximum possible percentage of reduction, 0 points to the minimum percentage, and a linear interpolation to the intermediate percentages. The positive points (+) are benefits.

Table 4 presents these calculations. Column (1) presents the emissions baseline considered in the Project Design Documents. Column (2) is the total estimated emissions reduction over an initial seven-year credit period (with the exception of the Baitun (PA_I) and Bajo de Mina (PA) hydroelectric power plants which were considered in terms of an initial reduction period of 10 years). Column (3) includes the average annual reductions for each project. Finally, column (4) is the result of the relationship between the average annual emissions reduction and the baseline emissions considered in the project.

Table 4. Normalization of annual reduction as % of baseline (Tons of C02e)

Key	Project reference number	Project's registered title	Annual emissions reduction (tons of C02e)	%	Normalization
Costa Rica					
CR_1	541	La Joya Hydroelectric Project (Costa Rica)	38 273	1.66	0.00
CR_2	8782	Chucás Hydroelectric Project	70 996	3.08	0.11
CR_3	4988	El General Hydroelectric Project	66 001	2.86	0.09
CR_4	9343	Torito Hydroelectric Power Plant	76 225	3.30	0.12
El Salvador					
ES	2607	El Chaparral Hydroelectric Project (El Salvador)	144 091	6.24	0.34
Guatemala					
GU_1	606	El Canadá Hydroelectric Project	118 527	5.14	0.26
GU_2	73	"Las Vacas" Hydroelectric Project	90 363	3.92	0.17
GU_3	5942	Palo Viejo Hydroelectric Project	258 423	11.20	0.71
GU_4	9713	Santa Rita Hydroelectric Plant	52 131	2.26	0.04
GU_5	1834	Xacbal Hydroelectric Project	311 438	13.50	0.88
Honduras					
HO	5071	La Vegona Hydroelectric Project	109 168	4.73	0.23
Panama					
PA_1		Baitun Hydroelectric Project	209 968	9.10	0.55
PA_2		Bajo de Mina Hydroelectric Project	137 007	5.94	0.32
PA_3	5960	Bajo Frío Hydro Power Project	151 560	6.57	0.36
PA_4	3237	Barro Blanco Hydroelectric Power Plant Project	66 934	2.90	0.09
PA_5	6588	Dos Mares Hydroelectric Project	349 444	15.14	1.00
PA_6	8452	Mendre Hydroelectric Power Plant Project	56 841	2.46	0.06

Source: Compiled by the authors based on data from UNFCCC (2020).

The second level environmental criterion, regarding the overexploitation of natural resources, refers to cases in which the project causes an exploitation of the local natural environment above the renewal rates in the corresponding cycles. This data is of a diverse nature, being both quantitative and qualitative, with four categories: null overexploitation (no overexploitation is observed), low, medium, and high (a clear case of severe overexploitation). These environmental impacts are costs, and so are given a negative sign, except for zero impact, meaning that normalization consists of high (-1), medium (-0.67), low (-0.333), and null (0) overexploitation (see table 3).

The third second-level environmental criterion is degradation by changes in the use of the natural environment (soil, water bodies, etc.), when the project's activities generate environmental pollution (from its installation to its operation), as harmful discharges to water bodies, affecting the quality of soils or ecosystems, including increases in pollutant emissions to the atmosphere. The data is diverse, both qualitative and quantitative, and is also organized into four categories: null (no damage to nature is observed), low, medium, and high degradation (high meaning clear and serious damage to nature). The normalization is similar to that of overexploitation (with values of -1, - 0.67, -0.333, and 0) (see table 3).

b) Economic criterion

The second level economic criterion of the amount of the initial investment is analyzed using monetary data (US dollars) for the disbursement made during the construction phase of the project. When normalized, these data were given a positive sign, as they are benefits. A value of 1 was assigned to the highest investment, 0 to the lowest, and interpolated values between the two values (see table 3).

Another second level economic criterion is job creation, with data on the number of jobs directly generated during the construction phase of the hydroelectric plants. For this effect, a benefit was given a positive sign (+) and the same normalization treatment was followed with linear interpolations between 0 and 1 (see table 3).

c) Social criteria

The second level social criterion regarding changes in regional infrastructure refers to modifications produced by the project in the host region, with a new construction or the renovation of an existing construction on one extreme of the spectrum and damage to infrastructure at the other. These documented observations were classified into three categories: infrastructure improvement, damage, and no change. In other words, there may be a benefit (improvement), cost (damage), or no effect (same, or no change). The first situation is assigned a positive value (1), the second is assigned a negative value (-1), and the third is null (0) (see table 3).

The other second-level social criterion refers to compensation to communities, via payments of damages to the local population incurred by a project. A compensation (benefit) was assigned a value of 1 and a value of 0 was assigned in the case of no compensation (see table 3).

d) Multi-criteria

Next follows a simple calculation for each criterion: the average total of points assigned to its respective second level components, yielding three separate averages (one for each criterion). Thus, we have the following equations:

$$A = (a_1 + a_2 + a_3) / 3 \quad (2)$$

$$E = (e_1 + e_2)/2 \quad (3)$$

$$S = (s_1 + s_2) / 2 \quad (4)$$

After normalization, the extreme scores of each criterion range from minimum values of A = -0.666, E = 0, S = -0.666, and maximum values of A = 0.333, E = 1, S = 0.666. Table 5 shows the results obtained from applying this process to the 17 projects.

Table 5. Unweighted evaluation, by first and second level criteria

Criteria	CR_1	CR_2	CR_3	CR_4	ES	GU_1	GU_2	GU_3	GU_4	GU_5	HO	PA_1	PA_2	PA_3	PA_4	PA_5	PA_6
A. Environmental (average)	-0.110	-0.188	0.030	-0.626	-0.443	0.086	0.056	-0.321	-0.318	-0.264	0.076	-0.039	-0.118	-0.212	-0.526	-0.333	-0.647
a1. Annual emissions reduction	0.000	0.105	0.089	0.122	0.340	0.258	0.167	0.707	0.045	0.878	0.228	0.552	0.317	0.364	0.092	1.000	0.060
a2. Overexploitation of natural resources	0	-0.670	0	-1	-0.670	0	0	-0.670	-1	-1	0	0	0	0	-1	-1	-1
a3. Environmental pollution	-0.33	0	0	-1	-1	0	0	-1	0	-0.67	0	-0.67	-0.67	-1	-0.67	-1	-1
Total (a1+a2+a3)	-0.330	-0.565	0.089	-1.878	-1.330	0.258	0.167	-0.963	-0.955	-0.792	0.228	-0.118	-0.353	-0.636	-1.578	-1.000	-1.940
E. Economic (average)	0.210	0.131	0.120	0.241	0.329	0.072	0.103	0.453	0.046	0.377	0.162	0.525	0.405	0.485	0.335	1.000	0.005
e1. Amount of initial investment	0.283	0.232	0.102	0.310	0.519	0.092	0.000	0.617	0.091	0.650	0.186	0.550	0.310	0.470	0.170	1.000	0.010
e2. Job creation	0.138	0.030	0.138	0.172	0.138	0.052	0.207	0.290	0.000	0.103	0.138	0.500	0.500	0.500	0.500	1.000	0.000
Total (e1+e2)	0.42	0.26	0.24	0.48	0.66	0.14	0.21	0.91	0.09	0.75	0.32	1.05	0.81	0.97	0.67	2.00	0.01
S. Social (average)	0.000	-0.667	-0.667	0.000	0.333	0.333	0.000	0.667	0.667	0.333	0.333	0.667	0.667	0.333	0.667	0.333	0.667
s1. Changes in regional infrastructure	1	-1	-1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1
s2. Compensation to communities	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1
s3. Local Conflicts	-1	-1	-1	-1	-1	0	0	0	0	-1	-1	0	0	-1	0	0	0
Total (s1+s2+s3)	0.0	-2.0	-2.0	0.0	1.0	1.0	0.0	2.0	2.0	1.0	1.0	2.0	2.0	1.0	2.0	1.0	2.0

Source: Compiled by the authors using data from Project Design Documents: UNFCCC (2019).

Weighting

If the primary objective of the projects is to contribute to governments' short-term development goals in host countries, and in light of authorities stated objectives in each country (expressed during the interviews), the economic criterion was assigned the greatest weight (40%), followed by the social criteria (35%), with the environmental criteria assigned the least (25%).

For each of the 17 projects studied, a net multi-criterion benefit function was calculated, according to the Simple Additive Weighting method.

$$B_i = P_a A_i + P_e E_i + P_s S_i \quad (5)$$

Where *A* is the average of the environmental criteria, *E* is the average of the economic criteria, *S* is the average of the social criteria, *i* is the project in question, P_a is the weighting of *A*, P_e is the weighting of *E*, and P_s is the weighting of *S*.

Therefore, the net benefit can be calculated as follows:

$$B_i = (0.25)A_i + (0.40)E_i + (0.35)S_i \quad (6)$$

Where *B* is the net benefit of the project *i* (with costs already discounted), taking into account local development priorities. The net benefits of the projects (sum of the weighted averages) give the following minimum, average, and maximum values:

a) Minimum: $(0.25)(-0.666) + (0.40)(0) + (0.35)(-0.666) = -0.400$

b) Average: 0.155

c) Maximum: $(0.25)(0.333) + (0.40)(1) + (0.35)(0.666) = 0.710$

Objectives of the evaluation

Based on this methodological framework, the evaluation focuses on the following five objectives:

To verify whether the average environmental benefit of the set of projects $(\Sigma P_a A_i / 17)$ is negative.

• To review whether economic and environmental differences between host countries are related to the divergent benefits of their CDM projects; in other words, whether there is a significant correlation between project benefit and variables such as GDP, GDP per capita, and global GHG emissions. It is expected that the countries with the largest economies and the highest GDP per capita will have the projects with the greatest benefits, as well as those with the highest GHG generation (thus reflecting an increased environmental awareness).

• To explore whether there is a clear learning curve related to negotiating CDM projects, thus generating greater benefits over time; that is, whether there is a significant correlation between benefit and project age (the younger the project, the greater the benefit).

• To see if there is a kind of externality of scale, in the sense that the larger the size (installed capacity) of the project, the greater the multi-criteria benefit.

• Finally, to calculate if the average net benefit is greater in terms of sustainability when there is no differentiated weighting (the three criteria are equal, so they are not weighted).

4. RESULTS

Data on the projects were processed according to the guidelines illustrated above. Table 6 shows the results of the calculations. The averages of the net benefits corresponding to the economic criterion are higher than those of the social criterion, while the social criterion has greater benefits than does the environmental criterion. This reflects host governments' values, which prioritize economic aspects. There is also an average environmental benefit from projects with a negative sign (environmental cost) in both scenarios.

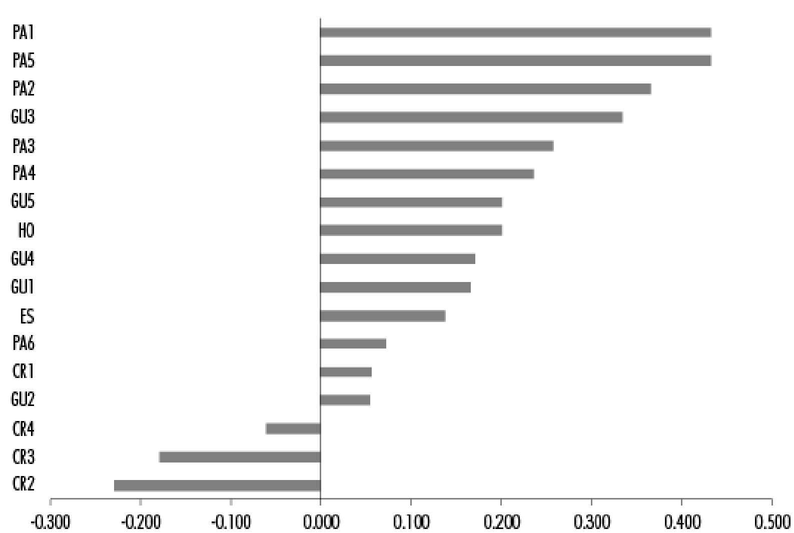
Table 6. Assessment of local priorities

Project	Environmental criterion	Economic criterion	Social criterion	Total
CR_1	-0.028	0.084	0.000	0.057
CR_2	-0.047	0.052	-0.233	-0.228
CR_3	0.007	0.048	-0.233	-0.178
CR_4	-0.157	0.096	0.000	-0.060
ES	-0.111	0.131	0.117	0.137
GU_1	0.021	0.029	0.117	0.167
GU_2	0.014	0.041	0.000	0.055
GU_3	-0.080	0.181	0.233	0.335
GU_4	-0.080	0.018	0.233	0.172
GU_5	-0.066	0.151	0.117	0.201
HO	0.019	0.065	0.117	0.200
PA_1	-0.010	0.210	0.233	0.433
PA_2	-0.029	0.162	0.233	0.366
PA_3	-0.053	0.194	0.117	0.258
PA_4	-0.131	0.134	0.233	0.236
PA_5	-0.083	0.400	0.117	0.433
PA_6	-0.162	0.002	0.233	0.074
Average	-0.057	0.118	0.096	0.156

Source: Compiled by the authors.

Figure 2, based on table 6, shows the results for each project. Three projects with net costs stand out (in Costa Rica: CR2, CR3, and CR4). Other projects show moderate net benefits while others achieve high net benefits, especially those in Panama.

Figure 2. Net benefit of each project



Source: Compiled by the authors with data from table 6

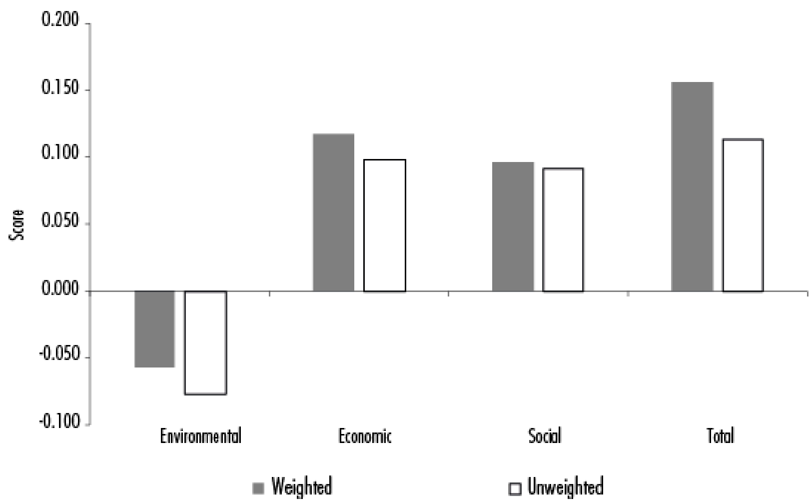
There does not seem to be any relationship between countries' results and their economic disparities, but there is a positive relationship with their GHG production. Effectively, Pearson's coefficient for the multi-criteria benefit related to GDP[5] is -0.248, -0.265 for GDP per capita[6] , 0.067 for the percentage of the population in poverty[7] , 0.203 for the Gini index[8] , and 0.682 for share of global GHG emissions (in %). It is worth pointing out that Pearson's coefficient between the multi-criteria benefit and share of global GHG emissions is quite high, and also that the relationship is positive. In other words, the higher the emissions, the greater the benefit the projects had.

On the other hand, there is a moderate positive correlation, not significant, between the multi-criteria benefit and project age. The corresponding Pearson quotient is 0.529. There is a slight positive trend, somewhat dispersed, of learning to negotiate improved CDM projects, but not as strong as could be hoped. It can also be seen that there is no significant correlation between the project's installed capacity (size) and the multi-criteria benefit. Pearson's coefficient for this relationship -0.150. This is a very low coefficient, suggesting that there is no externality of scale.

The three lowest-performing projects are located in Costa Rica. Comparing the Costa Rican government's behavior with that of the other four countries (based on Table 1), it is striking how proactive these four governments have been in legislative reforms in favor of the CDM and in attracting foreign investment in the projects' areas of interest (in line with their economic motivation), in contrast to the Costa Rican government, which was not so proactive in this regard. This suggests that this more active attitude, as an element of increased local government intervention, might be an explanatory factor for the evaluation results. This is consistent with findings from Fay *et al*. (2012), in the sense that an active industrial and energy policy in the host country plays a crucial role in the development of the CDM.

Finally, comparing the weighted evaluation (see table 6) with an unweighted evaluation in terms of sustainable development (see table 7), findings show that the net benefit in terms of sustainable development is lower, reflecting an incentive to seek differentiated benefits among the criteria, especially the economic one (see figure 3).

Figure 3. Average net benefit, by criterion



Source: Compiled by the authors with data from tables 6 and 7.

Table 7. Results without differentiated weighting

Project	Environmental criterion	Economic criterion	Social criterion	Total
CR_1	-0.110	0.210	0.000	**0.100**
CR_2	-0.188	0.131	-0.667	**-0.724**
CR_3	0.030	0.120	-0.667	**-0.517**
CR_4	-0.626	0.241	0.000	**-0.385**
ES	-0.443	0.329	0.333	**0.219**
GU_1	0.086	0.072	0.333	**0.491**
GU_2	0.056	0.103	0.000	**0.159**
GU_3	-0.321	0.453	0.667	**0.799**
GU_4	-0.318	0.046	0.667	**0.394**
GU_5	-0.264	0.377	0.333	**0.446**
HO	0.076	0.162	0.333	**0.571**
PA_1	-0.039	0.525	0.667	**1.152**
PA_2	-0.118	0.405	0.667	**0.954**
PA_3	-0.212	0.485	0.333	**0.606**
PA_4	-0.526	0.335	0.667	**0.476**
PA_5	-0.333	1.000	0.333	**1.000**
PA_6	-0.647	0.005	0.667	**0.025**
Average	-0.229	0.294	0.275	**0.339**

Source: Compiled by the authors based on data from table 5.

5. CONCLUSIONS

This article evaluates the multi-criteria net benefit of several large-scale hydroelectric plants installed in Central America and which are financed by the CDM, distinguishing between the net environmental, economic, and social benefits. The results of the multi-criteria evaluation, based on AHP guidelines and Simple Additive Weighting, and applied to the large scale CDM projects in Central America registered between 2000 and 2012, allow us to conclude that in this case, the CDM serves current host country priorities (short- and medium-term) more than sustainable development needs (long term), and therefore no longer fully complies with one of the Kyoto Protocol's primary objectives. This confirms what had already been found in several studies on Brazil and other developing countries in Africa and Asia (Burian and Arens, 2014; Karakosta *et al*., 2009; Sutter and Parreño, 2007). Economic progress occupies a privileged place among Central American governments' priorities, confirming what Karakosta *et al*. (2009) and Anagnostopoulos *et al*. (2004) have posited about the region. Consequently, economic benefits exceed social benefits and there are higher net environmental costs in the region. Findings also show that projects were not optimally executed, especially when considered in terms of sustainable development.

There seems to be no relationship between economic differences between countries and a country's results, but there is some positive correlation with their GHG production. In fact, the projects located in the countries with the highest degree of GHG emissions are those with the greatest multi-criteria benefits.

There is also a medium positive correlation, not significant, between the multi-criteria benefit and the age of the project. There is a slight positive trend, somewhat dispersed, of learning to negotiate improved CDM projects, but it is not as strong as could be hoped. This suggests that there is a local incentive to learn, although not in a robust way.

No significant correlation is found between project size and multi-criteria benefit, suggesting no externality of scale.

Finally, it can be seen that countries with governments proactive in developing CDM projects and attracting investment in the energy sector tend to attract projects with high multi-criteria benefits. This suggests that the existence of an active industrial and energy policy in the host country plays a crucial role in the development of the CDM (as argued by Fay *et al*., 2012). That being said, such governments lacked more proactive behavior on environmental and social issues, resulting in a number of damaging social and legal conflicts. This is an issue that warrants further research.

Appendix 1.

Appendix 1. Main characteristics of large-scale CDM hydroelectric projects registered by Central American countries between 2003-2012

Key	*Project reference number*	*Project registration title*	*Project sub-type (UNEP)*	*Validation start date*	*Annual emissions reduction (tons of CO2e)*	*%*	*Capacity installed (MW)*
Costa Rica							
CR1	541	La Joya Hydroelectric Project (Costa Rica)	Existing dam	10-Feb-2006	38 273	1.66	50
CR2	8782	Chucás Hydroelectric Project	New dam	18-Apr-2012	70 996	3.08	50
CR3	4988	El General Hydroelectric Project	River current	21-Apr-2009	66 001	2.86	40
CR4	9343	Torito Hydroelectric Power Plant	River current	17-Jun-2011	76 225	3.30	50
El Salvador							
ES	2607	El Chaparral Hydroelectric Project (El Salvador)	River current	24-Apr-2008	144 091	6.24	65
Guatemala							
GU1	606	El Canadá Hydroelectric Project	River current	9-Nov-2005	118 527	5.14	43
GU2	73	"Las Vacas" Hydroelectric Project	Existing dam	7-Mar-2005	90 363	3.92	45
GU3	5942	Palo Viejo Hydroelectric Project	River current	18-Aug-2010	258 423	11.20	85
GU4	9713	Santa Rita Hydroelectric Plant	River current	27-Dec-2011	52 131	2.26	24
GU5	1834	Xacbal Hydroelectric Project	River current	17-Nov-2006	311 438	13.50	94
Honduras							
HO	5071	La Vegona Hydroelectric Project	River current	4-Jun-2010	109 168	4.73	38
Panama							
PA1		Baitun Hydroelectric Project	River current	21-Sep-2011	209 968	9.10	87
PA2		Bajo de Mina Hydroelectric Project	River current	29-Sep-2011	137 007	5.94	57
PA3	5960	Bajo Frío Hydro Power Project	River current	24-May-2011	151 560	6.57	58
PA4	3237	Barro Blanco Hydroelectric Power Plant Project	New dam	27-Jun-2009	66 934	2.90	29
PA5	6588	Dos Mares Hydroelectric Project	River current	22-May-2010	349 444	15.14	118
PA6	8452	Mendre Hydroelectric Power Plant Project	River current	4-Sep-2009	56 841	2.46	20

Note: Both the Baitun and Bajo de Mina projects were renegotiated, so their validation began in June 2014 with registration on December 21 of the same year, and with MDC reference numbers 9616 and 9726, respectively.

Source: UNFCCC (2020).

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[1] The CDM is the only one of the three mechanisms under the Kyoto Protocol in which developing countries (also referred to as non-CDM countries, see Appendix 1) can participate. It is one of the most widespread and globally important instruments for the mitigation of GHG emissions. The other two mechanisms of the Protocol are Joint Implementation and Emissions Trading. Developed countries (Appendix 1) can participate in all three mechanisms (UNFCCC, 2002, Article 12).

[2] Multi-criteria methods have become increasingly widespread in recent years when evaluating economic, technological, and social processes (Greco et al., 2015).

[3] AHP was introduced in the 1970s by Saaty (1980), as a tool for analyzing decision processes. AHP is a method that prioritizes preferences (priorities or relative importance) for each of the criteria used to evaluate various alternatives. It allows problems to be solved via the collection of quantitative data and qualitative information through a hierarchical model (see Velasquez and Hester, 2013).

[4] Simple Additive Weighting is the oldest, best known, and most widely used multi-criteria analysis technique (Greco *et al*., 2015). It integrates the values and weights of the criteria into a single value for maximizing a benefit function (Qin *et al*., 2008): $Max\ W_1X_1 + W_2\ X_2 + W_3\ X_3 + W_4\ X_4$ where W1 refers to the weighting of each criterion, while X1 represents its value (usually normalized).

[5] World Bank (2019).

[6] IBID.

[7] CEPAL (2020a).

[8] CEPAL (2020b).