STRATCARBON
Strategic Climate Change Consulting

www.stratcarbon.cl

Draft for comments

WORKING PAPER: IMPACTS OF CARBON OFFSETS PROJECTS IN LATAM AND THE CARIBBEAN ECONOMIES

Eduardo López
Christian Patrickson

Table of content

1 Introduction

In recent years, Climate Change has increased its relevance in the international agenda. From 1992, with the creation of the United Framework Convention on Climate Change (UNFCCC) and numerous scientific reports from the IPCC, it has become increasingly clear that the argument of anthropogenic climate change can no longer be disputed. Fighting climate change, however, will require significant changes in the way countries develop their economies, as the world transitions to economic developing models that are less reliant on of fossil fuels and intensive GHG technologies.

The first attempt to curbing GHG emissions at a worldwide scale was the 1997 Kyoto Protocol (KP). This protocol separated the world in two, distinguishing between developed and developing countries. Under the protocol, the developed countries had the obligation to reduce their GHG emission approximately 5% below 1990 level, while developing countries had no mandatory obligations in GHG reductions. These countries could engage, however, with one of the flexibility mechanisms contemplated in the protocol, the Clean Development Mechanism (CDM) of Article 12 of the KP, through which it was possible to contribute with GHG emission reductions, which could be later used by developed countries to comply with their GHG obligations. The protocol also contemplated the Joint Implementation of Article 6 of the KP, which allowed the realization of GHG emission reduction projects between developed countries.

The CDM was introduced by the Kyoto Protocol as a flexibility mechanism and has become one of the most important carbon market instruments to date. While the first CDM project was registered in 2004, the CDM represents today the largest GHG emission offsetting scheme in the world. As of 01 September 2015 7,947 projects, including 283 Program of Activities projects (PoA), have been registered in more than 110 host countries. The CDM was designed as a pure offsetting mechanism, without the objective to generate a net reduction of greenhouse gas (GHG) emissions. In order to increase flexibility with respect to the location of the emission reduction activity within compliance schemes, the CDM allows to convert 100% of the achieved GHG reduction into tradable units (certified emission reductions, CER) which are normally used to emit the same amount of GHG elsewhere. In this way, the CDM operates as a zero-sum instrument, with no net impact on the global GHG emissions, although the increased level of flexibility achieved through the mechanism allows most cost-effective emission reductions which should lead to more ambitious mitigation targets in mandatory schemes.

The aim of this paper is to assess the relevance of the CDM by evaluating the actual and potential GHG emission reductions relative to historic country GHG emissions and future emission reduction targets. It also assesses the mechanism's contribution towards the addition of new renewable electric power generation capacity and its potential implications in the context of their future GHG emission strategy. With these results into consideration, the paper assesses the capacity of the CDM in mobilizing additional investment in the studied countries and how such investment translated into economic growth. Through the definition of a microeconomic analytical model and the definition of a set of micro and macroeconomic variables, the paper establishes relationships and sensitivities between these variables and the investment in climate mitigation actions performed through the CDM. The objective is to shed more clarity and a better understanding of the set of economic variables other than carbon price, that would affect the use of such mechanisms in the context countries' future GHG mitigation strategy.

2 CDM role and impact on GHG emission reductions

Under the 1997 Kyoto Protocol (KP) countries could engage with the Clean Development Mechanism (CDM) which allows emission reduction projects to issue Certified Emission Reduction units (CERs). Through the CDM, GHG emission reduction projects implemented under the rules of the mechanism from the year 2000 onwards could generate GHG emission reduction units or Certificate of Emission Reductions (CERs), which could be traded among parties and used or cancelled for compliance purposes. Until 2019, the mechanism had generated 2 $GtCO_2e$ of GHG emission reductions and mobilized approximately US$ 420 billion of investment in GHG mitigation projects in developing countries. Despite these big figures, if put into perspective, they are dwarfed by the real numbers required both in emission reductions and in mobilized capital if the world is to have a reasonable chance of meeting the climatic goals established by the latest climate accord, the Paris Agreement, which in its Article 2 establishes a goal of maximum 2 °C, or preferably 1.5 °C average rise in world temperature by the end of the century.

The new Paris Agreement, which will supersede the Kyoto Protocol from 2020 onwards, also contemplates flexibility mechanisms. Article 6.2 offers the possibility of voluntary collaboration among parties, by using ITMOs (Internationally Transferred Mitigation Outcomes) and Article 6.4 introduces a new offset mechanism, the Sustainable Development Mechanism (SDM), which will probably replace the existing CDM. Despite that currently more than half of the countries, parties to the UNFCCC that ratified the Paris Agreement have explicitly expressed their intention of using market-based mechanism to comply with their climate goals or considered the possibility of doing so, the rulebook of Article 6 could not be finalized in the last COP 24 in Katowice, Poland in 2018. An agreement around Article 6 is therefore expected at COP 25.

The analysis was circumscribed to the main country users of the CDM in the Latin American and the Caribbean region. According to the Table 1, these countries are Brazil, Mexico, Chile and Colombia,

Table 1. Total Registered CDM Projects and issued CERs in LATAM and Caribbean countries reduced

Country (LATAM AND CARIBBEAN)	Registered CDM projects (N° of projects)	(%)	(%) (Accum.)	Total CERs issued (N° CERs)	(%)	(%) (Accum.)
Brazil	**343**	**34,2%**	**34,2%**	**144.054.261**	**54,6%**	**54,6%**
Mexico	**192**	**19,1%**	**53,3%**	**33.190.293**	**12,6%**	**67,2%**
Chile	**103**	**10,3%**	**63,5%**	**28.706.881**	**10,9%**	**78,0%**
Colombia	**65**	**6,5%**	**70,0%**	**14.504.229**	**5,5%**	**83,5%**
Peru	61	6,1%	76,1%	5.480.502	2,1%	85,6%
Argentina	46	4,6%	80,7%	15.870.610	6,0%	91,6%
Ecuador	33	3,3%	84,0%	2.501.144	0,9%	92,6%
Honduras	30	3,0%	87,0%	2.612.867	1,0%	93,6%
Uruguay	25	2,5%	89,4%	813.308	0,3%	93,9%
Panama	23	2,3%	91,7%	339.615	0,1%	94,0%
Guatemala	20	2,0%	93,7%	4.234.375	1,6%	95,6%
Costa Rica	17	1,7%	95,4%	1.757.095	0,7%	96,3%
Dominican Republic	14	1,4%	96,8%	79.587	0,0%	96,3%
Nicaragua	12	1,2%	98,0%	3.088.901	1,2%	97,5%
El Salvador	7	0,7%	98,7%	2.369.243	0,9%	98,4%
Bolivia	4	0,4%	99,1%	2.873.275	1,1%	99,5%
Cuba	2	0,2%	99,3%	1.018.055	0,4%	99,9%
Jamaica	2	0,2%	99,5%	376.478	0,1%	100,0%
Paraguay	2	0,2%	99,7%	6.819	0,0%	100,0%
Bahamas	1	0,1%	99,8%	0	0,0%	100,0%
Belize	1	0,1%	99,9%	0	0,0%	100,0%
Guyana	1	0,1%	100,0%	0	0,0%	100,0%
Total	**1.004**	**100%**		**263.877.538**	**100%**	

Source: UNFCCC CDM project database.

This research looks at both the actual GHG emission reductions in the form of issued credits and the potential of GHG emission reductions associated to the registered projects. This analysis also contemplates comparing these results with the GHG emission reductions implied in the latest NDCs from the selected countries.

Table 2. BAU and NDC Country net GHG emission projection sources

Brazil	Third biennial update report to the UNFCCC and the GWP values from the Second Assessment Report from the IPCC. Available at: https://unfccc.int/sites/default/files/resource/2018-02-28_BRA-BUR3_ENG_FINAL.pdf
	Federative Republic of Brazil Intended Nationally Determined Contribution towards achieving the objective of the United Nations Framework on Climate Change. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/BRAZIL%20iNDC%20english%20FINAL.pdf
	Climate Tracker, Brazil. Available in: https://climateactiontracker.org/countries/brazil/2019-06-17/
Mexico	Sexta Comunicación Nacional y Segundo Informe Bienal de Actualización ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático (revisada). Available at: file:///C:/Users/Christian%20Patrickson/Downloads/832_6a_Comunicacion_Nacional.pdf
	Mexico INDC 03.30.2015. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mexico%20First/MEXICO%20INDC%2003.30.2015.pdf
Chile	Chile's third biennial update report. Available at: https://unfccc.int/sites/default/files/resource/5769410_Chile-BUR3-1-Chile_3BUR_English.pdf
	Propuesta: "Contribución nacional determinada a nivel nacional (NDC) de Chile. Primera actualización 2019". Available at: file:///C:/Users/Christian%20Patrickson/Downloads/Propuesta_NDC_Chile_2019.pdf
	Climate Tracker, Chile. Available at: https://climateactiontracker.org/countries/chile/
Colombia	Biennial update report (BUR). BUR 2. National inventory report. Available at: https://unfccc.int/documents/194659
	Nationally determined contribution, Colombia. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/Colombia%20iNDC%20Unofficial%20translation%20Eng.pdf

The main data source used in this research was the CDM project database, obtained from the CDM registry. The database contained data from all CDM projects submitted until December 31st 2018 to the mechanism. The main database fields used in this research are the following:

- Project identification: ID number, project name, etc.
- Type and subtype.
- Emission reduction estimated for each crediting period.
- Total CERs issuance per project.
- Annual CER issuance per project.
- Investment per project.
- Annual investment per project.
- Operational costs per project.
- Annual operational costs per project.

In order to assess the relevance of the CDM, this study compares the actual and potential emission reduction of registered projects in the period 2000-2018 with the countries' total annual GHG emission and the GHG emission reductions implied in their latest NDCs until 2030. Table 2 shows the data sources used to obtain and project each country's BAU and NDC GHG emissions until 2030.

The historic data for country GHG emissions were directly obtained from the Biennial Update Reports (BUR) to the UNFCCC. In the case of Brazil, however, the total annual GHG emissions from 2000 to 2015 had to be calculated using the reported CO_2, CH_4 and N_2O emissions and the GWP values from the Second Assessment Report from the IPCC. The BAU and NDC GHG emissions were linearly projected up to 2030, using expected BAU and NDCs GHG emission expected for certain years, according to the information sources mentioned above.

2.1 Relevance of the CDM emission reductions in the studies countries

To assess the relevance of CDM emission reductions during the studied period, this research calculated two ratios: the actual CDM issuance versus the countries GHG emission before CDM emission reductions and the potential CDM issuance versus the countries GHG emission, also before the actual CDM emission reduction.

For the actual CDM average ratio, the following equation was used:

$$R_{actual} = \frac{CERs}{\sum_{y=2000}^{y=2018}(N\ GHG_y + CERs_y)} \tag{1}$$

Where:

R_{actual} =	Ratio between the total actual CDM emissions reductions and the total gross country GHG emissions (before the actual CDM emission reductions). [%]
CERs =	Total actual CERs issuance from 2000 to 2018. [N° CERs].
$N\ GHG_y$ =	Annual net country GHG emissions. [N° CERs].
$CERs_y$ =	Actual annual CERs issuance. [N° CERs].

For the potential CDM average ratio, the following equation was used:

$$R_{potential} = \frac{P\ CERs}{\sum_{y=2000}^{y=2018}(N\ GHG_y + CERs_y)} \tag{2}$$

Where:

$R_{potential}$ =	Ratio between the total potential CDM emission reductions and the total gross country GHG emissions (before the actual CDM GHG emission reductions). [%]
P CERs =	Total potential CERs issuance from 2000 to 2018. [N° CERs].
$N\ GHG_y$ =	Annual net country GHG emissions. [N° CERs].
$CERs_y$ =	Actual annual CERs issuance. [N° CERs].

The second ratio involved estimating the total emission reduction potential of registered CDM projects for each country during the studied period. This was accomplished by using the estimated amount of emission reductions (CERs) expected for the first crediting period of each project and the crediting period extension for each CDM project activity, both of which were available in the project database provided by the UNFCCC. It must be noted, though, that using the projects' first crediting period CER emission estimate may not necessarily be the most precise estimate for the emission reductions of project activities with renewable 7-year crediting periods, however the second and third credit emission GHG emission reduction estimates were not available for the second and third crediting periods for all the registered. Nevertheless, this criteria was used for all the assessed countries, therefore it provides a reasonable reference for comparison purposes.

The above equations correspond just to an approximation of the actual and potential impact of the CDM in relation to the countries' net GHG emissions before accounting for CDM emission reductions, since the annual net GHG emission most likely reflect CDM emission reductions of projects that operated during the analyzed period, but which could not issue the credits under the mechanism. This was, however, the best approximation that could be found for the purpose of this analysis and the same criteria was applied for all the countries. The results of this analysis is shown for each country in the table "CDM relevance in terms of country net GHG emissions (2000 to 2018)".

Table 3. CDM relevance in terms of country net GHG emission, 2000-18

Period analyzed: 2000 to 2018		Brazil	Mexico	Chile	Colombia
Total actual CDM emission reductions	(MM tCO_2e)	144	33	29	15
Actual CDM emission reductions vs country net GHG emissions	(%)	0.4%	0.3%	**4.7%**	0.4%
Potential CDM emission reductions	(MM tCO_2e)	449	170	102	64
Potential CDM emission reductions v.s. net GHG emissions	(%)	1.3%	1.8%	**16.7%**	1.6%

Source: Own elaboration based on UNFCCC CDM and country reported data.

Table 3 illustrate how the CDM has and could further contribute to GHG mitigation in all of the selected countries. In relative terms, Chile despite being the smallest country of the four, was one of the most active players in the CDM relative to its GHG emissions in the studied period, as it presents the highest average annual CDM GHG emission reductions relative to its annual GHG emissions. This is probably due to the following reasons: Chile was an early and relevant user (i.e. in absolute terms) of the mechanism from the beginning. The second reason has to do with the fact that Chile, unlike the other three analyzed countries, has lower net GHG country emissions due to the relevant role played by its forests, which act as an important carbon sink in the total accounting of its annual net GHG emissions[1]. Brazil, probably due to its size, is by far the most relevant user of the mechanism in absolute terms. However relative to its annual GHG net emissions, places behind the other three analyzed countries. Leaving aside the case of Chile, it can be concluded that on an annual basis, the CDM has an interesting potential for GHG emission reductions, particularly considering emission reductions over longer periods of time (e.g. 5 or 10 years). As a reference, the third commitment period of the EU ETS (2013-2020) considered a 1.73% of annual reduction in the total GHG allowances distributed. This was increased to 2.2% GHG reductions in the fourth commitment period (2021-2030).

[1] According to Chile's third biennial update report, Chilean forests captured approximately 60% of gross GHG emissions in 2016.

2.2 CDM role in the development of renewable power generation sources

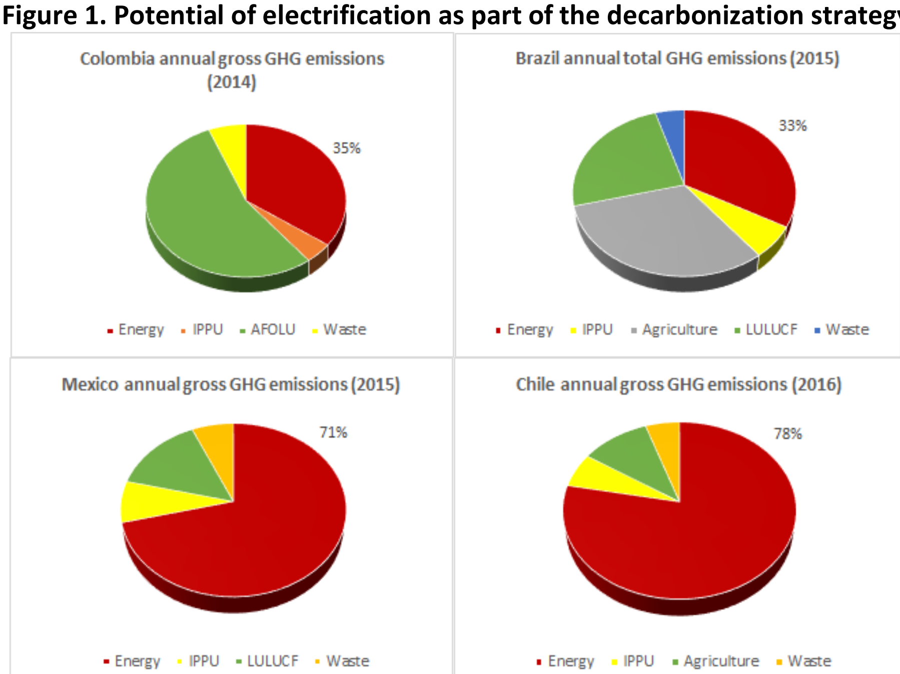
Another variable that was analyzed was the role played by the mechanism in fostering renewable, low carbon electric power installed capacity in each country. The analysis consisted in calculating the contribution of CDM electric power capacity to the total electric power capacity added in the period 2000-2018. The evolution of the total electric power generation capacity for each country was obtained from official government web pages and Power Industry reports. The installed power capacity associated to power-related CDM project activities was sourced directly from the Project Design Documents of all CDM project activities covered by this study (700 projects). The result of this analysis is shown for each country in Table 4.

Table 4. CDM relevance in terms of country's electric power generation capacity

Period analyzed: 2000 to 2018		Brazil	Mexico	Chile	Colombia
Electric power generation capacity in 2000	(GW)	74	41	10	13
Electric power generation capacity in 2018	(GW)	159	76	25	17
CDM power generation capacity contribution from 2000 to 2018	(GW)	18	5	3	1
CDM power generation capacity contribution from 2000 to 2018	(%)	21%	13%	23%	**26%**

Source: Own elaboration based on UNFCCC CDM data and public country reports on electric power generation capacity.

Figure 1. Potential of electrification as part of the decarbonization strategy



Source: Table "BAU and NDC country net GHG emission projection sources" in this paper.

As can be seen, the CDM has played a significant role in the development of renewable low carbon electric capacity in the studied countries. Colombia shows the highest CDM contribution (26%) to the total increase of electric power generating capacity in the studied period. Chile and Brazil show lower, but still high and comparable numbers for this metric.

These figures are significant since in these countries as in probably the rest of the countries in the studied region, the electrification of the energy sector is generally a key part of their mitigation strategy. This means that the lower the GHG intensity of the electric power matrix, the more effective the GHG mitigation effect associated to the increased electrification of the energy sector in the respective countries. Figure 1 shows the relevance of the energy related GHG emission relative to the net annual country emissions in the studied countries:

2.3 CDM emission reductions versus the GHG emission reductions in the countries NDCs

The following analysis considered a comparison between the actual and potential CDM emission reductions to the GHG emission reductions implied in the studied countries' latest NDCs up to 2030. These ratios were determined by using the following equations:

$$R_{NDC\ actual\ CDM} = \frac{CERs}{\sum_{y=NDC\ start}^{y=2030}(BAU\ GHG_y - NDC\ GHG_y)} \quad (3)$$

And,

$$R_{NDC\ potential\ CDM} = \frac{P\ CERs}{\sum_{y=NDC\ start}^{y=2030}(BAU\ GHG_y - NDC\ GHG_y)} \quad (4)$$

where:

$R_{NDC\ actual\ CDM}$ =	Ratio between the total actual CDM emission reductions during 2000 to 2018 and the estimated GHG emission reductions associated to the latest NDC, from the start of the NDC until 2030. [%]
$R_{NDC\ potential\ CDM}$ =	Ratio between the total potential CDM emission reductions during 2000 to 2018 and the estimated GHG emission reductions associated to the latest NDC, from the start of the NDC until 2030. [%]
CERs =	Total actual CER issuance from 2000 up to 2018. [N° CERs].
P CERs =	Total potential CER issuance from 2000 up to 2018. [N° CERs].
$BAU\ GHG_y$ =	BAU net GHG country emissions, estimated from information of each country's latest NDC or using the average net GHG growth rate of the last 5 years. [tCO_2e/yr].
$NDC\ GHG_y$ =	Reduced net GHG country emissions, estimated from information of each country's latest NDC. [tCO_2e/yr].
NDC start =	Year in which the country NDC starts [year].

The actual and potential CDM emission reduction were obtained directly from CDM project database, while the implied GHG emission reduction for each of the studied countries required projecting the BAU and NDC GHG country emissions until 2030 and calculating the cumulated difference between the two GHG emission projections. The BAU and the NDC GHG emission projections were done using data sources presented in the table "BAU and NDC country net GHG emission projection sources", previously shown in this section of the paper.

The following table shows a comparison between CDM GHG emission reductions and the implied GHG emission reductions in the latest NDCs of the four selected countries, relative to their estimated BAU GHG emission until 2030. The comparison distinguishes between actual CDM GHG emissions reductions achieved (i.e. issued credits) and total potential CDM emission reductions that could be achieved during the 2000 to 2018 period. The main objective of this analysis is to determine whether the GHG emission reduction CDM legacy is relevant considering the countries' NDCs up to 2030. As a result, this comparison allows for some inconsistency among the countries' indicators, since not all NCSs consider the same starting year.

Table 5. CDM relevance in terms of country's latest NDCs

CDM period: 2000 to 2018; NDCs up to 2030		Brazil	Mexico	Chile	Colombia
Total actual CDM emission reduction v.s. unconditional NDC emission reduction	(%)	9.2%	1.2%	**22.0%**	2.0%
Total potential CDM emission reduction v.s. unconditional NDC emisions reductions	(%)	28.6%	6.2%	**78.0%**	8.9%

Source: Own elaboration based on UNFCCC CDM data and NDC country report data.

For both type of indices Chile presents the highest figures, distantly followed by Brazil, which also presents high figures compared the ones of the remaining countries. The potential CDM emission reduction versus the unconditional NDC commitment ratio is perhaps the best indicator to highlight the relevance of the GHG emission reductions associated to the CDM in the corresponding countries. Unless the actual GHG emission reduction indicator, the potential indicator shows the total GHG emission reductions associated to projects that could have been generated have the conditions have been appropriate.

Table 5 allows to conclude that market mechanisms like the CDM have the potential to deliver a significant portion of the GHG mitigation effort that is currently being proposed by some countries in their NDCs. Therefore, contribution of market-based mechanisms could be considered as an important component of the countries' future climate mitigation strategies. This is particularly so, considering that towards the end of the last decade, the world suffered subprime financial crisis (2008) and the European debt crises (2012) which combined with the absence of new mitigation ambition from the international community, triggered the collapse of international carbon prices and the consequent stall of new GHG project generation under the mechanism. Had the circumstances been different (i.e. more favorable), the contribution of the CDM could have probably been higher.

With this into consideration, it becomes convenient to improve the understanding of the conditions and variables that could affect the performance of market mechanisms in the future, in order to better assess and understand the potential impact that market mechanisms could play in countries' future GHG mitigation strategies. The next sections of this paper, provides an analytical framework that allows to assess the sensitivity of GHG emission reductions relative to external conditions such as carbon price, economic growth, interests rates and other variables that would help to better understand the factors that can affect the use and performance of market mechanisms in the coming years.

3 CDM Projects and Investment

This section assesses the capacity of the CDM to mobilize additional investment in the different sectors in which CDM projects have been implemented and how such investment has translated into economic growth in the studied countries. This analysis also attempts to assess possible relationships between the generation of CDM emission reductions and external variables such as the international carbon price, local economic growth and international commodity prices among other variables. This will shed some more clarity on which are the key variables, relevant to foster climate mitigation action in the scale the new Paris Agreement requires.

3.1 A stylized model for Investment in GHG emission reduction project[2]

Let us consider a representative firm developing a GHG Emission Reduction Project. A specific feature of these projects is that the firm obtains additional revenues from the sale of emission reduction certificates (E), the price of which is associated with the carbon price (Pc) and the amount of which is directly associated with the production derived from the project, i.e. carbon revenue can be expressed as $\mathrm{P_c\theta E}$, where θ of the share of GHG emission reduction that is likely to be sold as offset in the carbon market.

The firm produces output using capital K as its only input

$$\mathrm{q = f(K)} \tag{5}$$

f(.) is the production function, which is increasing (i.e, $\frac{\partial q}{\partial K} \equiv q_K > 0$) and concave in k (i.e., , $\frac{\partial^2 q}{\partial K^2} \equiv q_{KK} < 0$. reflecting a positive marginal capital productivity which is decreasing as capital rises.

The cost of a unit of capital is R per period. In period t, given that P is the sale price and c is the operational costs the firm decides its level of capital with the objective of maximizing its after-tax profits, which results from subtracting taxes from the economic profits associated to the project (π^e). Taxes are calculated from accounting profits (π^c), which we assume that only a fraction ϕ of cost of capital is taxable and, therefore. ϕ represents a measure of investment tax credit.

$$\underset{\{\mathrm{K}\}}{\mathrm{Max}} \quad \pi^{\mathrm{e}} - \mathrm{t_c}\pi^{\mathrm{c}} \tag{6}$$

Where $\pi^{\mathrm{e}} = (\mathrm{P - c})\mathrm{q} + \mathrm{P_c\theta E - RK}$ and $\pi^{\mathrm{c}} = (\mathrm{P - c})\mathrm{q} + \mathrm{P_c\theta E} - \phi\mathrm{RK}$. Replacing these two expressions in () we obtain after tax profits:

$$\underset{\{\mathrm{k}\}}{\mathrm{Max}} \quad (1 - \mathrm{t_c})[(\mathrm{P - c})\mathrm{q} + \mathrm{P_c\theta E}] - (1 - \mathrm{t_c}\phi)\mathrm{RK} \tag{7}$$

The first-order condition of this problem, resulting from deriving respect to K and equalizing to zero, is:

---

[2] This model borrows Jorgenson (1963) and Hall and Jorgenson (1967).

$$(1-t_c)\left[(P-c)+P_c\theta E_q\right]q_K=(1-t_c\phi)R \tag{8}$$

From which we conclude that the firm finds its optimal level of capital when its capital cost is equal to the marginal productivity of capital, adjusted by taxes and carbon-based revenues.

As an example, and in order to find a close-form solution, let firstly assume that GHG emissions are positively related to output such as $\epsilon = E_q \frac{q}{E} > 0$, and secondly let consider a output function such as, $f(k) = AK^{\alpha}$, from which we yield $\frac{\partial q}{\partial K} \equiv q_K = A\alpha \frac{q}{K}$

Given those assumptions, we can obtain and expression for the optimal level of capital per unit of GHG emissions, $k = \frac{K}{E}$

$$k^* = \left[\frac{1-t_c}{1-t_c\phi}\right]\frac{\left[(P-c)\frac{q}{E}+P_c\theta\epsilon E\right]A\alpha}{R} \tag{9}$$

In this expression we can identify several factors influencing the optimal capital level. Firstly, in the first bracket, we note the impact of corporate taxes and investment tax credit. In particular, the higher the corporate taxes the lower k*, and the higher the investment tax credit the higher k*. Secondly, we can see the inverse impact on k* of R, the cost of capital. Thirdly, we can observe the inverse impact of operational margin per unit of GHG emissions. Finally, we can identify the impact of carbon based revenues which depends on the tradability of GHG emissions (θ) and, on the elasticity of GHG emission to output. More generally, this expression can be summarized as:

$$k^* = F\left(\underset{-}{t_c}\ ;\ \underset{+}{\phi}\ ;\ \underset{+}{\frac{Pq}{E}}\ ;\ \underset{-}{\frac{cq}{E}}\ ;\ \underset{+}{P_c\theta\epsilon}\ ;\ \underset{-}{R}\right) \tag{10}$$

Where the sign below each variable is the sign of the partial derivative. That is, capital increases when tax credit rate (ϕ), expected revenues per GHG emission, and carbon-related factors ($P_c\theta\epsilon$) rise, and decreases as corporate taxes rate (t_c), operating expenses (c) and capital costs rise. Nonetheless, k* is the desired capital in the absence of adjustment costs, and what we see in practice is that firms do not immediately adjust to this desired level of capital, because they face adjustment costs before and during the development of the project which are associated to the reorganization of the current operation, staff and workers training, among others. When considering these costs, we can assume a partial adjustment mechanism such as:

$$I_t = k_{t+1} - k_t = \gamma(k^* - k_t) \tag{11}$$

The parameter γ represent adjustment speed of capital to its desired level, the higher this parameter the lesser time the adjustment takes. Once replaced k* this expression can be reformulated as:

$$I_t = F\left(\underset{-}{t_c};\ \underset{+}{\phi};\ \underset{+}{P};\ \underset{-}{c};\ \underset{+}{P_c};\ \underset{+}{q};\ \underset{-}{R};\ \underset{+}{\gamma};\ \underset{-}{k_t}\right) \tag{12}$$

Which is an expression for the investments or capital expenses of the project. It should also be noted that the adjustment depends on γ, but also on how far the capital level is k*. If k_t , i.e. the actual capital level, is too low, then capital expenses should be increased to reach k*.

3.2 Data

The model described in the previous subsection is estimated using annual data from several databases and sources for the period 2000-19, which we describe in the following paragraphs.

a) Capital and operational expenses (CAPEX and OPEX).

Capital and operational expenses were estimated using general assumptions by reviewing each CDM emission reduction project in order to obtain more precise values. The total investment value was obtained directly from the Project Design Documents (PDDs) and/or the financial analysis spreadsheet that accompanied the PDDs, whenever available. The local currencies were converted into US$ considering the exchange rate of the corresponding local currencies at the starting date of the project activity. The same procedure was followed with the operational expenses. In cases in which no financial data was available in the PDDs or in the CDM project web site, investment and operational expenses were estimated considering other emission reduction projects of the same scale, type, sub-type and in the same country. Also, investment and the operational expenses were corrected taking into account the additional investment and operational expenses related to the GHG emission reduction project activity. This correction allows to more clearly identify the investment and operational values associated to the emission reduction initiative instead without including the part of the investment and OPEX that would have occurred anyway under the baseline scenario. The corrected investment and operational expense values were prorated throughout the years in the same way as the original values were in the first place.

Table 6. Capital Expenses by countries and sector, 2000-19
(per reduced tCO_2)

Brazil

	2000-04	2005-09	2010-14	2015-19
Biomass energy	72.4	15.8	4.4	
Hydro	12.7	20.4	219.7	7.1
Landfill gas	0.8	1.1	4.6	0.5
Methane avoidance	0.8	2.3	0.9	
Wind & Solar	0.4	10.2	308.8	4.9
Rest	3.7	7.4	8.2	
Average	9.1	10.7	116.6	3.2

Chile

	2000-04	2005-09	2010-14	2015-19
Biomass energy	9.5	17.4	14.7	
Hydro	2.8	36.8	111.4	
Landfill gas		5.6	1.6	
Methane avoidance	4.2	1.8	1.2	
Wind & Solar		7.2	222.2	10.6
Rest	0.7	0.8	44.7	
Average	1.6	12.6	109.5	3.7

Colombia

	2000-04	2005-09	2010-14	2015-19
Biomass energy		2.3	1.1	
Hydro	5.3	9.5	141.7	33.5
Landfill gas		4.2	3.4	0.2
Methane avoidance	0.0	5.4	2.5	
Wind & Solar	233.0			
Rest	2.3	269.3	83.2	1.9
Average	2.5	66.0	58.2	9.4

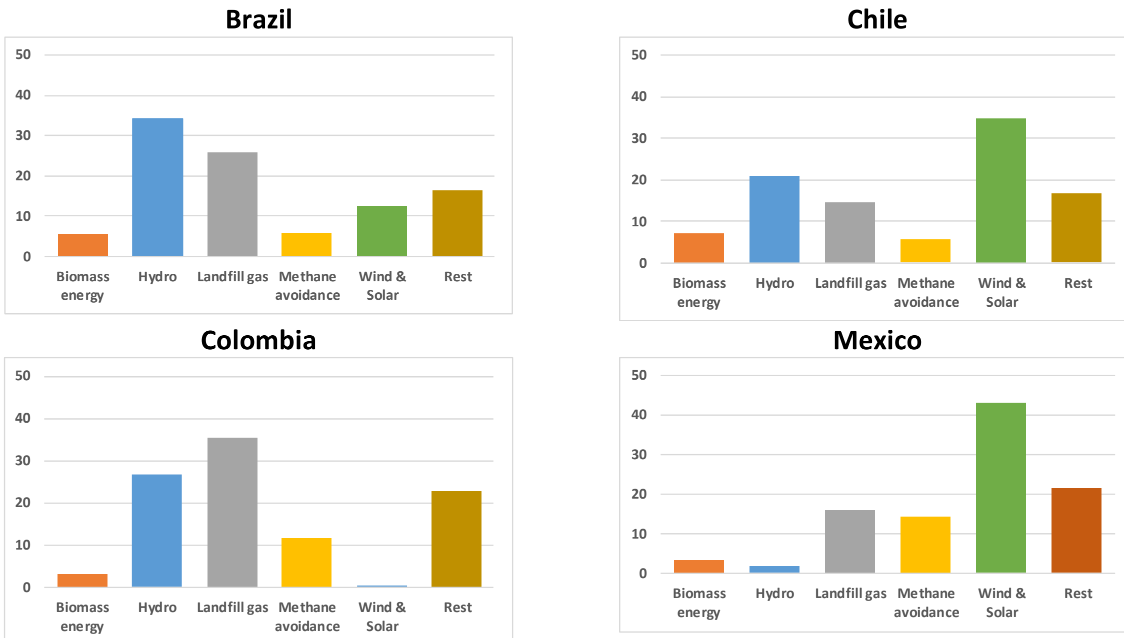
Mexico

	2000-04	2005-09	2010-14	2015-19
Biomass energy		2.7	28.4	21.4
Hydro	27.2	26.7	84.2	
Landfill gas		6.6	7.1	0.1
Methane avoidance	0.2	3.0	1.9	
Wind & Solar		41.1	145.1	2.7
Rest		4.0	127.7	
Average	0.5	20.6	93.8	1.9

Source: author´s calculations with data from CDM pipeline Database

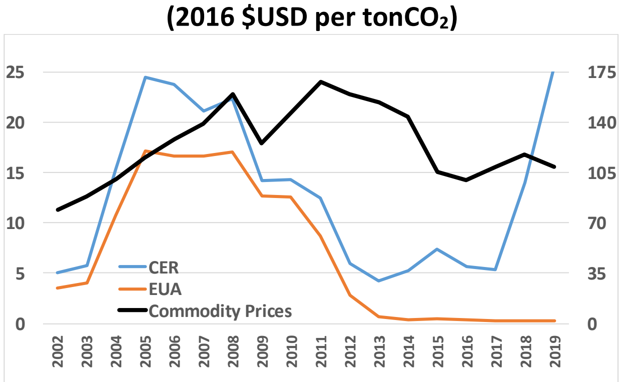
Table 6 firstly reports that the peak of investments in GHG emission reducing projects took place in 2010-14 after the 2007-09 U.S. financial crisis, which partly accounts for the lags of these sort of project implementation. Secondly, the table also gives an account of the high diversity of the data in terms of the sectors to which the projects belong and the sponsoring countries. Thirdly, there are differences among countries in terms of sectoral contribution to country´s GHG emissions reduction through these sort of project. For example, in Figure 2, Chile and Mexico, Wind and Solar projects have the highest share in the reduction, while in Brazil and Colombia Hydro and landfill gas projects are more important.

Figure 2. Sectoral contributions to annual GHG emission reductions (% of total)



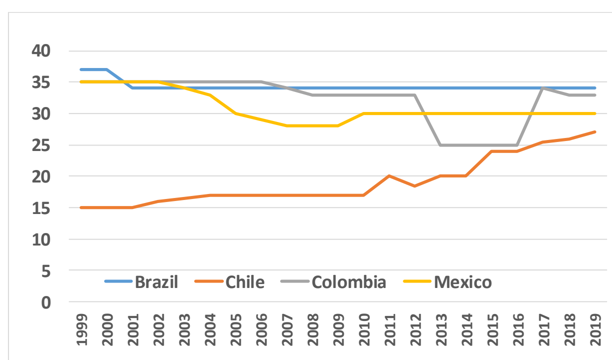
Source: author´s calculations with data from CDM pipeline Database- For each country, figures represent the sector´s share of total yearly GHG emission reductions as described in PDD in CP1

Figure 3. Real prices of Offsets and Carbon, 2000-19 (2016 $USD per ton$CO_2$)



Source: ISIS Exchange, IMF-WEO Database

Figure 4. Statutory corporate taxes, 2000-19 (%)



Sources: KPMG Corporate Tax database, OECD Tax Database, PWC Worldwide Tax summaries

b) Offsets and Carbon Real Prices

During the high-price & high-demand period of the CDM market before the US crisis of 2007-09, a myriad of different tCO_2 prices were available, which established an obstacle for market functioning regarding contract standardization. These prices differ due to different factors, such as Instrument type (: e.g. offsets or allowances), market type (e.g. compliance or voluntary), trading mechanism (e.g. over the counter or exchange), project offsets characteristics (e.g. types, location, registration dates, types, vintages, etc.), allowance characteristics (e.g. vintage). In our analysis we used CER and EUA spot prices for 2000-19, obtained from the ISIS exchange. CERs and EUAs prices have been the most well-known and used carbon asset types in trading carbon in the last 15 years. Real Prices are calculated by using Bureau of Labor Statistic's Producer Price Index.

In Figure 3 the high association between carbon-based real prices and real commodity prices can be observed for the pre-crisis period. However, after 2009 these prices tend to delink each other mainly because the reduced demand for offset assets.

c) Corporate Taxes

Data on corporate taxes are obtained from different sources such as KPMG Corporate Tax database, OECD Tax Database, and PWC Worldwide Tax summaries. Although changes in corporate tax rate are relatively infrequent during the sample, their informational content is significant for the investment decisions. Figure 4 shows that Brazil has kept unchanged its corporate tax rate, while Chile has increased it during the las 20 years. Mexico and Colombia reduced their corporate tax rate during the pre-crisis period and kept unchanged since then in the case of Mexico and increased to previous levels in the case of Colombia since 2016.

d) Macro Data and commodity prices

Macroeconomic factors are an important driver for the investment decisions. We proxy capital cost by using the real rate of the U.S. 10-year T-Bill since we do not have availability of data on capital depreciation and capital gain. To proxy the cyclical position of the economy we use the GDP gap by using GDP data from IMF-WEO database and by using a Hoddrick-Prescott Filter we estimate the trend GDP. This data is shown in Figures 5 and 6, where it can be observed the inversed correlation between real interest rate and commodity prices, and the high international correlation between the countries and world macroeconomic cycles over the sample period.

Figure 5. Commodity prices and Long-Term real interest rates

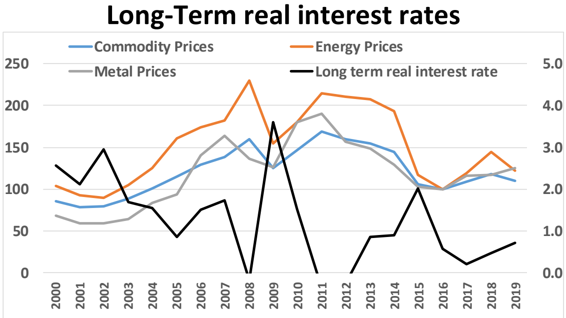
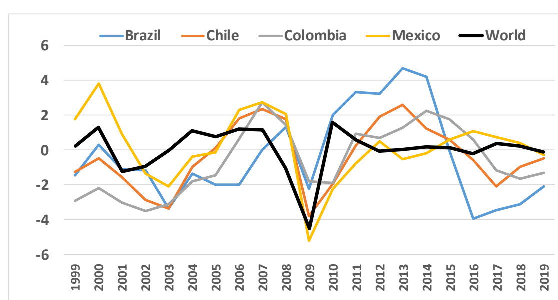


Figure 6. Output gap (%)



Source: author´s calculations with data from IMF-WEO database

3.3 Results

Following the conceptual framework regarding the decision on CDM´s investment now we turn to our estimation results of fixed-effect panel data models.

a) Econometric Results

In the selection of fixed-effect model we consider the fact that our model is highly simplify description of the CDM's investment decision at a project level which in our data may have a several idiosyncratic omitted variables. On the other hand, the nature of the explanatory variables may suggest that there is a correlation with the omitted variables and, consequently fixed effects models may provide a means for controlling for omitted variable bias (Allison,2009).

Based on the theoretical framework develop in previous section, to explain the behavior of CDM´s investment, we estimate a standard model for business investment, which assumes that investment increases when aggregate demand or output gap, real commodity prices and operational profits increases, and it reduces when corporations' financing cost (i.e., real interest rate) and corporate taxes increases. A small selection of important studies includes Summers (1981), Feldstein et al (1983), Auerbach and Hassett (1992), Jason G. Cummins, Hassett, and Hubbard (1996). Auerbach (2002), and Hasset and Hubbard (2002). Generally speaking, this research finds adverse effects of corporate income taxes on investment, although studies offer different estimates of magnitudes

The econometric estimation is conducted with annual data for 2003-2019 (or the longest available time series data), The empirical specification is the following[3]

$$\mathrm{CAPEX_{it}} = \beta_{0i} + \beta_1 t_c + \beta_2\left(P_t^{car}/C_t^{opex}\right) + \sum_{i=1}^{5}\beta_{2i}D_i\left(P_t^{car}/C_t^{op}\right) + \beta_3 R_t + \beta_4 P_t^{com} + \beta_5\left(GDP_t/GDP_t^{*}\right) + \beta_6 \mathrm{CAPEX_{it-1}} + u_{it} \quad (13)$$

Where $CAPEX_{it}$ corresponds to the capital expenses associated to the sector i in the year t; t_c is the statutory corporate income tax rate; P^{car} is the carbon-based Price; C^{opex} corresponds to the operational expenses associated to the sector i, R refers to the financial capital cost proxied by the 10-year T-bill real interest rate. The model also include the domestic output gap (GDP_t/GDP_t^{*}) and the real international commodity prices (P_t^{com}) as proxies for the domestic and international business cycle that could have an impact on CDM's investments. Finally, in order to account for the heterogeneous impact of the carbon-based-price to operational expenses margin (P_t^{car}/C_t^{opex}) on the investment, we include dummy variables (D_i) which are 1 for the sector i and 0 otherwise. Data have been grouped into 6 sectors: Biomass Energy (1), Hydro (2), Landfill Gas (3), Methane Avoidance (4), Wind and Solar Energy (5) and Rest (6). The grouping process was based on the relative importance of each sector; and the need to capture the highest share by using the lowest number of groups. The 5 groups clearly identified account for around 80-85% of the capital expenses in each country over the sample period.

[3] Jorgenson and Siebert (1968) provide a derivation of the accelerator model. Based on the theory underlying the model, the empirical specification is typically estimated as in Oliner and others (1995).

Table 7. Main results for Capital Expenses on CDM´s Emission-reducing projects in LATAM
Fixed-effects Panel Data models[1/]
Dependent Variable: Capital Expenses per reduced tCO_2 (in logs) [2/ 3/]

$$\mathbf{CAPEX_{it}} = \boldsymbol{\alpha_{0i}} + \boldsymbol{\alpha_1 t_c} + \boldsymbol{\alpha_2}\left(\mathbf{P}_t^{car}/\mathbf{C}_t^{opex}\right) + \sum_{i=1}^{5} \boldsymbol{\alpha_{2i}}\mathbf{D_i}\left(\mathbf{P}_t^{car}/\mathbf{C}_t^{op}\right) + \boldsymbol{\alpha_3}\mathbf{R_t} + \boldsymbol{\alpha_4}\mathbf{P}_t^{com} + \boldsymbol{\alpha_5}\left(\mathbf{GDP_t}/\mathbf{GDP}_t^{*}\right) + \mathbf{u_{it}}$$

	Brazil		Chile		Colombia		Mexico	
	P^{CER}/C^{OP}	P^{CAR}/C^{OP}	P^{CER}/C^{OP}	P^{CAR}/C^{OP}	P^{CER}/C^{OP}	P^{CAR}/C^{OP}	P^{CER}/C^{OP}	P^{CAR}/C^{OP}
α_1	-	-	-0.60 **	-0.47 **	-0.01 *	0.03 *	0.11 *	-0.06 *
$\alpha 2$	0.78 **	0.80 **	-0.11 *	-0.03 ***	0.35 **	0.69 **	0.47 **	0.43 **
$\alpha 20$	2.99 **	-2.21 **	1.65 **	1.99 **	0.30 *	0.91 **	-0.11 *	-0.12 *
$\alpha 21$	0.92 **	1.23 **	0.26 *	0.34 **	-0.31 **	-0.09 *	1.48 **	1.19 **
$\alpha 22$	0.46 *	0.69 *	3.41 ***	3.15 ***	0.49 **	1.01 ***	1.05 ***	1.26 **
$\alpha 23$	1.99 **	2.06 **	-1.12 **	-0.94 *	-0.14 *	-0.20 *	2.87 ***	1.82 ***
$\alpha 24$	0.13 *	0.16 *	-0.35 **	-0.27 *	0.75 **	1.16 **	0.44 **	0.42 **
$\alpha 26$	1.79 **	1.84 **	-0.15 *	-0.05 *	0.75 **	1.16 **	0.41 **	0.34 *
$\alpha 3$	-0.22 *	-0.33 *	-0.42 **	-0.41 **	-0.09 *	-0.39 **	-0.39 **	-0.49 **
$\alpha 4$	2.27 *	2.11 *	4.93 ***	4.21 ***	3.40 ***	6.70 ***	3.63 **	1.63 *
$\alpha 5$	0.09 *	0.16 *	0.10 *	0.02 *	0.25 **	0.17 **	0.09 **	0.07 *
$\beta 6$	0.68 ***	0.65 ***	0.22 **	0.20 **	-0.01 *	0.14 **	0.41 **	0.42 **
Periodo	2003-19	2003-19	2004-15	2004-15	2003-17	2003-17	2004-16	2004-16
N	74	74	50	50	42	42	49	49
R2 aj	0.395	0.369	0.476	0.452	0.540	0.596	0.689	0.618
DW	1.81	1.97	1.91	1.87	2.51	2.72	1.73	1.69
Log Likelihood	-134.3	-107.4	-91.6	-92.7	-61.9	-60.8	-61.3	-66.3
$\sigma_{residuos}$	1.68	1.34	1.86	1.90	1.40	1.31	1.05	1.16

1/ The table presents the results based on robust covariances estimated with the White diagonal method. Results remain generally unchanged when the White cross-section (period clustered) or White-period (cross section clustered) methods are used. The specifications without time fixed effects are adjusted for cross-sectional heteroskedasticity
2/ "*", "**" and "***" denote significance at 10, 5, and 1 percent levels, respectively
3/ reported parameters are calculated as $\alpha_{2i} = \frac{\beta_2+\beta_{2i}}{1-\beta_6}$ .Signficance is tested using a Wald Test for restrictions.
Intecept are not reported.

Given the nature of our focus we are more interested in the long-run responses of the investment to shocks in the explanatory variables. These parameters can be retrieved from the estimated model as

$$\alpha_i = \frac{\beta_i}{1-\beta_6} \tag{14}$$

Where $1-\beta_6$ represent the speed of adjustment of investment and its reciprocal is the time period that the adjustment takes.

The general interpretation of these parameters is that they register the percentage response of the unit capital expense when the corresponding variable is changed in one percentage unit. These parameters are reported in Table XX, which result from a process of reduction and parametrization intended to find the most parsimonious empirical specification.

Generally, the results lend strong support to the conceptual framework discussed above. First, we can observe for each country there are 2 alternative specifications which refers to different proxies for the carbon-based price. In both case, the margin respect to the unit operational expense is used but in one case we utilize the EUA-Carbon Price and, in the other case, we use the offset CER price. The parameters are generally statistically significant at the usual percent levels.

As expected, in general we can observe positive carbon-based price elasticities over countries and sectors, but there are heterogeneous responses depending the sector. This is reflected on the lower than the unit figure for the aggregated response and the larger than one and almost zero and negative in some case for the sectorial case. This result is a reflection, in some cases, of the high heterogeneity of projects in the sample despite the aggregation, and, in other cases, of the lack of data over the full period in some individual projects and sector.

There is also an inverse relationship between the cost of capital and the investment per unit of reduced carbon across all specifications, and in particular, the impact is less than the unit, fluctuating between 0.1 and 0.5, which means that an increase of 100 basis points in the real long-term interest rate raises investment per unit of reduced carbon by between 0.1% and 0.5% in the long run. With regard to commodity real price sensitivity, we can see the high elasticity of projects in Chile and Colombia, as opposed to Brazil and Mexico. For example, if the actual price of commodities rises by one percentage point, for example in the case of Chile the investment per unit of carbon would increase by about 0.4 percentage points. Another factor influencing the investment decision in emission reduction projects is the cyclical situation of the economy, and according with the results, each point of output gap add between 0 y 0.25 percentage points in the investment per unit of reduced carbon. finally, it can be observed that there are differences in the speed of adjustment of the investment between the 4 countries as reported by parameter b6 in each specification. For example, investments in Brazil and Mexico seem to take longer until they find their optimum level, unlike Chile and Colombia.

b) Growth potential of the CDM's investment: a preliminary note

An important topic for the discussion on climate change concerns the growth potential of emission reduction projects. While there may be trade-offs at the cross-sectoral level which may dampen the impact of growth, in this paper we assume that the main macroeconomic effect of emission reduction projects is that they raise the capital stock of the economy and consequently raise growth rate over the investment period. In this direction, we could establish a linkage between reducing carbon emissions and economic growth considering the following "accounting" relationship

$$\Delta\%\mathrm{PIB} = \left[\frac{\partial\Delta\%\mathrm{PIB}}{\partial \mathrm{I}}\right] \cdot \left[\frac{\partial \mathrm{I}}{\partial \mathrm{CAPEX}^{\mathrm{CDM}}}\right] \cdot \left[\frac{\mathrm{E}^{\mathrm{CDM}}}{\mathrm{E}}\right] \cdot \Delta\mathrm{E} \qquad (15)$$

Where the first factor is known as ICOR (Incremental Capital Output Ratio) and comes from the economy's structural characteristics, expressing the needed increase in investment ratio (I) to achieve 1% of GDP (D%PIB); the second factor is the response of economy's investment ratio (I) to CDM's investments per reduced tons of CO_2 ($CAPEX^{CDM}$); and the third factor is the share of CO_2 reduction associated to CDM's investment (E^{CDM}) to economy's net CO_2 emission (E). Fourth factor is the economy's committed CO_2 emission reduction effort in the context of Paris agreement (DE).

In order to obtain a preliminary assessment, we have estimated a stylized aggregate model for each country along the following lines

Growth	$\hat{y} = \alpha_0 + \alpha_1 i_t + \alpha_2 Z_t + u_t$	(16)
Investment	$i = \beta_0 + \beta_1 \left(\frac{CAPEX^{CDM} EmR}{GDP}\right) + \beta_3 \left(\mathrm{y_t}/\mathrm{y_t^*}\right) + \beta_3 Z_t + \varepsilon_t$	(17)
CDM investment per unit of reduced carbon	$CAPEX^{CDM} = \gamma_0 + \gamma_1 \, \mathrm{P}_t^{car}/\mathrm{C}_t^{\mathrm{opex}} + +\gamma_2 \left(\mathrm{y_t}/\mathrm{y_t^*}\right) + \gamma_2 Z_t + v_t$	(18)

The model, which solves simultaneously $\hat{y}$, i, and $CAPEX^{CDM}$ includes also lags for the variables and allow to identify the impact of the aggregated investment on the product, the impact of CDM investment on the aggregate investment and the behavior of CDM investments according to the models estimated above. In this model, Z is a vector of exogenous variables, which include the real long-term interest rate and the commodity real price. We report the elasticity of growth to investment and the elasticity of investment to $CAPEX^{CDM}$ in the table XX. More details are reported in the annex I.

Based on this simple model we evaluate the differential impact on the economy´s growth of CDM´s investments for a given scenario of the exogenous variables of the model. For these purposes, the simulation is carried out for the period 2020-2030 and it is assumed that

a) the actual price of commodities and the real long-term interest rate are in their long-term estimates;
b) economies are in a steady state, which means that the output gap is zero over the projection horizon;
c) international inflation is assumed to be 2% per year;
d) domestic inflation is consistent with the inflation targets of each country's central banks; and
e) exchange rates are projected using purchasing power parity

For the analysis we use the emission reduction commitments that each country has declared in the context of the Paris Agreement and, based on their previous behavior, we assume that a fraction of this commitment will be carried out through CDM projects, as indicated in Table 3 of Section 2. In doing the evaluation we build three scenarios. The base scenario is built on the previous assumptions and assumes that there are no CDM investments, which more or less describes the current situation. This is operationalized assuming unit investments are null for the entire projection horizon. In defining this scenario, the aggregate growth and investment rate projections have been calibrated to be consistent with the projections up to 2024 reported in the latest World Economic Outlook report prepared by the IMF in October.

In the first scenario, we allow CDM investments and let the equation to be project CDM investment for given exogenous variables. Finally, in a third scenario, we consider an exogenous adjustment to the model in which it is assumed that the investment is greater than the level projected by the model. In particular, taking into account the experience 2002-2005, where there was a significant increase in investment in emission reduction projects in the early years of the initiative. In this case we assume that in the first 5 years there is a factor that doubles unit investments between 2020 and 2025, reflecting a scenario of exuberance in emission reduction investment.

Table 8. Response of GDP growth to CDM's Investments

	Brazil	Chile	Colombia	Mexico
BAU GHG emissions incl. LULUCF (Cum 2020-30)	15,425,035	1,305,637	3,293,937	9,727,500
NDC GHG emissions (Cum 2020-30)	14,222,697	1,175,000	2,713,597	7,323,343
Emission reductions required to comply with NDC (Cum 2020-30)	1,202,337	130,637	580,340	2,404,157
Effort through CDM projects				
K tCO_2e	14,666	21,816	8,703	39,913
% Reductions required to comply NDC	1.2	16.7	1.5	1.7
Base Scenario				
GDP Growth (average 2020-30)	2.2836	3.3192	3.6277	1.9967
Investment Ratio (average 2020-30)	14.768	23.145	22.057	20.134
CAPEX Ratio (% GDP)	-	-	-	-
CAPEX (US$ per reduced tone of CO_2)	-	-	-	-
Scenario with CDM's Investments				
GDP Growth	2.2837	3.3841	3.6291	1.9967
Investment Ratio	14.826	23.514	24.782	20.147
CAPEX Ratio (% GDP)	0.0038	0.0715	0.3493	0.0012
CAPEX (US$ per reduced tone of CO_2)	0.7049	0.2325	3.965	0.0102
PV of Additonal GDP (% GDP 2019)	0.006	2.807	0.299	0.0006
Scenario with CDM's Investments and push factor				
GDP Growth	2.2838	3.4461	3.6304	1.9967
Investment Ratio	14.877	23.865	27.053	20.157
CAPEX Ratio (% GDP)	0.0071	0.1395	0.6405	0.0021
CAPEX (US$ per reduced tone of CO_2)	1.2007	0.438	6.882	0.0171
PV of Additonal GDP (% GDP 2019)	0.0121	5.374	0.551	0.0010
Memorandum				
Elasticidad Crecimiento-Inversion	0.0012	0.176	0.000	0.0002
Elasticidad Inversión-CDM CAPEX	0.0007	0.004	0.031	0.0002

The results of this exercise are reported in Table 8. First, it is noted that Chile has historically shown a higher fraction of emissions through emission reduction projects, i.e. around 15% compared to around 2% of the other countries analyzed. Second, while the differential impacts on the long-term growth rate are small, what is interesting for the analysis is the cumulative effect of investments, which are presented as the present value of increases GDP between 2020 and 2030, discounted at the long-term real interest rate. As noted, in Chile the incorporation of the reduction effort through CDM investment would result in a gift of almost 3% of GDP in 2019. This is partly because Chile rests on almost 10 times on investment in CDM projects compared to the rest of the region. If the values were normalized so that all countries would make an effort similar to Chile's, for Brazil it would mean 0.08% of GDP in 2019, for Colombia 3.33% and for Mexico 0.1%. These values would obviously be even higher in the event that there was a greater increase in investment swings in the early years

The previous exercises are not intended to be a definitive answer to this issue, but to raise a point that needs to be considered with regard to the mobilization of resources by the private sector in the fight against climate change. This point is related to the magnitude of existing trade-offs resulting from the productive transformation associated with carbon neutrality. Therefore, a future agenda of analysis should refer to establishing the direction and magnitude of these trade-offs in such a way as to have a convincing argument for greater private sector participation.

4 Conclusions

The main conclusions that can be drawn from this paper are the following:

The potential GHG emission reductions delivered by the CDM does not represent a high percentage of total GHG country emissions among the main users of the mechanism, however the numbers are comparable to the annual GHG emission reduction observed in other GHG compliance systems. That means that over long period of time (5 or 10 years), these mechanism have the potential to deliver significant GHG emission reductions.

Considering the latest NDCs of the studied countries, the CDM has the potential to deliver a significant portion of the implied GHG mitigation effort, particularly in case of the main users of the mechanism. Therefore, countries should consider the role and potential contribution of these mechanisms in their future climate change mitigation strategy. For example, main country users of the CDM could implement new domestic policy that would favor the reactivation of dormant CDM projects, through which they could reactivate GHG mitigation capacities at a national level and at the same time, deliver high-quality mitigation outcomes. The transition of existing projects, methodologies and CDM credits under the new climate regime of the Paris agreement is clearly justified in the case of countries have been strong users of the CDM, like Chile, Brazil and Mexico.

The CDM has played an important role in promoting carbon-neutral and renewable electric power capacity among the main country users of the mechanism in the LAC region. This has strong implications for countries in the LAC region, since they all tend to show high GHG emissions associated to the energy sector. More so, considering the high correlation observed between energy consumption growth rates and economic growth rates. This correlation tends to be particularly high among developing countries, which comprise all the LAC region. Fostering market mechanisms like the CDM, could positively help LAC countries to decarbonize the energy matrix, which will most likely be a key component of the long-term GHG mitigation strategy of the countries in the region.

Sectorial heterogeneity of response of CDM investment to carbon price signals calls for a well-designed system of incentives that emphasize selectivity over neutrality in order to promote these mechanisms. Taxes are an important factor, especially in Chile. If responses to corporate taxes is a proxy for green taxes, this calls for a clear definition of rates, activities to be taxed, sources of emission to be taxed and exemptions. Particularly high sensitivity to international output cycle, such as real interest rates and commodity prices.

Countries should take into consideration the growth impacts when designing their future GHG mitigation targets and factor them into their future climate change strategies. CDM's projects can be a desired mechanism in order to have both reducing GHG emissions and increase economy's long-run growth.

STRATCARBON
Strategic Climate Change Consulting

5 References

Abel, Andrew B. (1983). “Optimal Investment under Uncertainty.” American Economic Review 73 (1):228–33.

Allison, P. (2009), “Fixed Effects Regression Models“, Series of Quantitative Applications in the Social Sciences) 1st Edition

Auerbach, Alan J., and Kevin Hassett. 1992. “Tax Policy and Business Fixed Investment in the United States.” Journal of Public Economics, 47(2): 141–70

Auerbach, Alan J. 2002. “Taxation and Corporate Financial Policy.” In Handbook of Public Economics, Volume 3, ed. Alan J. Auerbach and Martin Feldstein, 1251–92. Amsterdam: North-Holland.

ASOCIACIÓN DE GENERADORAS DE CHILE, 2019. Boletín del Mercado Eléctrico Sector Generación, Santiago, Chile, (No defined editorial), 26 p. (Available at: http://generadoras.cl/media/page-files/716/Boletin%20Enero%202019.pdf, consulted during September, 2019).

CENTRO DE ESTUDIOS DE LAS FINANZAS PÚBLICAS, 2006. El Sector Eléctrico en México, 1980-2006, Mexico, (No defined editorial), 47 p. (Available at: https://www.cefp.gob.mx/intr/edocumentos/pdf/cefp/cefp0732006.pdf, consulted during September 2019).

COMISIÓN INTERSECRETARIAL DE CAMBIO CLIMÁTICO, 2018. Sexta Comunicación Nacional y Segundo Informe Bienal de Actualización ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático, First edition 2018, Ciudad de México, (No defined editorial), 757 p. (Available at: file:///C:/Users/Christian%20Patrickson/Downloads/832_6a_Comunicacion_Nacional.pdf, consulted during September, 2019).

CLIMATE ANALYTICS, NEW CLIMATE INSTITUTE, 2019. Climate Action Tracker. (Available at: https://climateactiontracker.org/about/the-consortium/, consulted during September, 2019).

Cummins, Jason G., Kevin A. Hassett, and R. Glenn Hubbard. 1996. “Tax Reforms and Investment: A Cross-Country Comparison.” Journal of Public Economics, 62(1–2): 237–73.

DEPARTAMENTO DE PESQUISAS E ESTUDOS ECONOMICOS, 2019. Energía Eléctrica. Brazil, (No defined editorial), 120 p. (Available at: https://www.economiaemdia.com.br/EconomiaEmDia/pdf/infset_energia_eletrica.pdf, consulted during September, 2019).

FEDERATIVE REPUBLIC OF BRAZIL, 2010. Second National Communication of Brazil to the United Nations Framework Convention on Climate Change. Brasilia, Brazil, (No defined editorial), 264 p. (Available at: http://euroclimaplus.org/intranet/_documentos/repositorio/Segunda%20Com%202010-ilovepdf-compressed%20(1).pdf, consulted during September, 2019).

Feldstein, Martin, Louis Dicks-Mireaux, and James Poterba. 1983. “The Effective Tax Rate and the Pretax Rate of Return.” Journal of Public Economics, 21(2): 129–58.

GENERADORAS DE CHILE, 2018. Boletín del Mercado Eléctrico Sector Generación, Santiago, Chile, (No defined editorial), 26 p. (Available at: http://generadoras.cl/media/page-files/395/Boletin%20Sector%20Generacion%20enero%202018%20-%20Generadoras%20de%20Chile.pdf, consulted during September, 2019).

GOBIERNO DE CHILE, 2019. Contribución Determinada a nivel Nacional (NDC) de Chile primera actualización 2019, Santiago, Chile, (No defined editorial), 41 p. (Available at: https://mma.gob.cl/wp-content/uploads/2019/10/Propuesta_actualizacion_NDC_Chile_2019.pdf, consulted during September, 2019).

GOBIERNO DE COLOMBIA, 2015. Colombia first NDC, República de Colombia, 10 p. (Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/Colombia%20iNDC%20Unofficial%20translation%20Eng.pdf, consulted during September, 2019).

GOBIERNO DE LA REPÚBLICA DE MEXICO, 2015?, Mexico First NDC, Mexico, (No defined editorial), 8 p. (Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mexico%20First/MEXICO%20INDC%2003.30.2015.pdf, consulted during September, 2019).

Hall,R.E. and D. Jorgenson (1967), “Tax Policy and Investment Behavior”, The American Economic Review, Vol. 57, No. 3 (Jun., 1967), pp. 391-414.

Hassett, Kevin A., and R. Glenn Hubbard. 2002. “Tax Policy and Business Investment.” In Handbook of Public Economics. Volume 3, ed. Alan J. Auerbach and Martin Feldstein, 1293–1343. Amsterdam: North-Holland.

IDEAM, PNUD, MADS, DNP, CANCILLERÍA, 2018. Segundo Reporte Bienal de Actualización de Colombia ante la CMNUCC, República de Colombia, 180 p. (Available at: https://unfccc.int/sites/default/files/resource/47096251_Colombia-BUR2-1-2BUR%20COLOMBIA%20SPANISH.pdf, consulted during September, 2019).

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 1995. IPCC Second Assessment Climate Change 1995. (No defined editorial and publishing place), 73 p. (Available at: https://www.ipcc.ch/site/assets/uploads/2018/06/2nd-assessment-en.pdf, consulted during September, 2019).

Jorgenson, D. (1963), “Capital Theory and Investment Behavior”, The American Economic Review, Vol. 53, No. 2, Papers and Proceedings of the Seventy-Fifth Annual Meeting of the American Economic Association (May, 1963), pp. 247-259

Jorgenson, Dale W., and Calvin D. Siebert. (1968). “A Comparison of Alternative Theories of Corporate Investment Behavior.” American Economic Review 58 (September): 681–712.

Oliner, Stephen, Glenn Rudebusch, and Daniel Sichel. (1995). “New and Old Models of Business Investment: A Comparison of Forecasting Performance.” Journal of Money, Credit, and Banking 27 (3): 806–26.

MINISTERIO DE ENERGÍA, 2018. Anuario Estadístico de Energía 2018, Santiago, Chile, (No defined editorial), 162 p. (Available at: https://www.cne.cl/wp-content/uploads/2019/04/Anuario-CNE-2018.pdf, consulted during September, 2019).

MINISTRY OF ENVIRONMENT, 2018? Chile’s Third Biennial Update Report, Santiago, Chile, (No defined editorial), 379 p. (Available at: https://unfccc.int/sites/default/files/resource/5769410_Chile-BUR3-1-Chile_3BUR_English.pdf, consulted during September, 2019).

MINISTRY OF FOREIGN AFFAIRS, MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATIONS AND COMMUNICATIONS, 2019. Brazil’s third biennial update report to the United Nations Framework Convention on Climate Change. Brazil, 88 p. (Available at: https://unfccc.int/sites/default/files/resource/2018-02-28_BRA-BUR3_ENG_FINAL.pdf, consulted during September, 2019).

SECRETARIA DE ENERGÍA, 2017. Prospectiva del Sector Eléctrico 2017-2031, Mexico, (No defined editorial), 176 p. (Available at: https://www.gob.mx/cms/uploads/attachment/file/284345/Prospectiva_del_Sector_El_ctrico_2017.pdf, consulted during September, 2019).

SECRETARIA DE ENERGÍA, 2018. Reporte de Avance de Energías Limpias Primer Semestre 2018 México 2018, Mexico, (No defined editorial), 21 p. (Available at: https://www.gob.mx/cms/uploads/attachment/file/418391/RAEL_Primer_Semestre_2018.pdf, consulted during September, 2019).

SIMEC, UPME, 2019. Sistema de Información Eléctrico Colombiano, Colombia. (Available at: http://www.siel.gov.co/Inicio/tabid/38/Default.aspx, consulted during September, 2019).

Summers, Lawrence H. 1981. “Taxation and Corporate Investment: A q-Theory Approach.” Brookings Papers on Economic Activity, 1: 67–140.