 DOES MEXICO BENEFIT FROM THE CLEAN DEVELOPMENT MECHANISM? A MACROECONOMIC AND ENVIRONMENTAL GENERAL EQUILIBRIUM ANALYSIS

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Nicolas PECASTAING
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Jean-Marc Montaud · Nicolas Pécastaing

Abstract:

Since 2000, the Clean Development Mechanism (CDM) under the Kyoto Protocol has included southern countries in the fight against climate change by encouraging northern countries to make environmentally friendly direct investments at the lowest cost in these developing nations. Even if CDM investments have enjoyed great success, the question of how host countries benefit from these investments seems insufficiently explored. Therefore, this article offers a quantitative assessment of the economic and environmental impacts of CDM investments for the specific case of Mexico. We use a computable general equilibrium model that features environmental topics, to simulate the demand and supply effects induced by these investments. Numerical simulations reveal the growth potential and important fund of development that represents the CDM for Mexico, though the environmental impact appears broadly mixed.

KEYWORDS: Clean Development Mechanism, computable general equilibrium, Mexico

JEL CLASSIFICATION: D58, O13, Q56

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Introduction

Involving southern countries in the fight against climate change, without hindering their development, is a major challenge for the international community. The Clean Development Mechanism (CDM), under the Kyoto Protocol, currently constitutes the primary tool for enabling northern countries (Annex 1 countries) to make environmentally friendly direct investments at lower costs in developing countries (Non-Annex1 countries), through the carbon credit granted in proportion to the greenhouse gas reductions achieved. These CDM investments have enjoyed great success since their introduction in November 2004. As of 01/04/2013, 6600 CDM projects were registered worldwide, for a total investment of

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1 These “non-Annex I” countries must have adopted the Kyoto Protocol and appointed a designed national authority, responsible for validating each project.
approximately US$215.4 billion (Fenhann, 2013; UNFCCC, 2012). Yet the question of how host countries benefit from this additional development funding source seems insufficiently explored by economic literature (for a review, see UNFCCC, 2010) and reveal a lack of a quantitative assessment after ten years of CDM. If early studies adopted prospective quantitative approach (Banuri and Gupta, 2000; Mathy et al., 2001), most research features qualitative multi-criteria analyses (Kolshus et al., 2001; Huq, 2002; Begg et al., 2003; Sutter, 2003; Anagnostopoulos et al., 2004; Olhoff et al., 2004; Olsen, 2007; UNFCCC, 2012) and reflect heterogeneous insights suffering from some weaknesses. Majority appear then focused more on environmental or technical transfer topics, rather than development issues; they tend to assign arbitrary weights to different indicators of development; and in some cases, they depend on criteria specified by the designed national authority of each host country when selecting projects (Olsen, 2007; Olsen and Fenhann, 2008; Boyd et al., 2009; Alexeew et al., 2010; Bumpus and Cole, 2010; Subbarao and Lloyd, 2011). In this context, many authors have emphasized the need to apply an international standard to rate CDM projects, in accordance with their contribution to various development dimensions (Cosbey et al., 2005; Schlup, 2005; Cosbey, 2006; Sutter and Parreno, 2007; Olsen and Fenhann, 2008).

This study seeks to contribute such ex post quantitative assessment of CDM on a single host country, using the specific case of Mexico where this mechanism has been a significant funding source for investments since it ratified the Kyoto Protocol in September 2002. At the start of 2013, 215 CDM projects already had been registered or planned in this developing country, equivalent to nearly US$13.2 billion, making it the fifth largest recipient of such funds. In order to simulate numerically the impact of these foreign CDM investments on the Mexican economy, we use a computable general equilibrium (CGE) model in order to reveal the various interdependencies that generate such an exogenous shock on demand, supply, income, and prices in this economy. Moreover, because of the nature of the CDM, we also extend this standard CGE analysis by including an environmental perspective, which can reveal the ecological consequences of these economic changes, in accordance with the conceptual framework of the System of Environmental Accounting used in Mexico. The first section, details the main hypotheses of the CGE model built for Mexico and its economic and environmental databases. The next one presents the numerical simulations and the quantitative results obtained.

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Olsen and Fenhann (2008) show for example that the potential benefits of CDM projects may concern five criteria: job creation, growth, air quality, access to energy, and well-being of the people.
1. CGE Model

Model equations

The model, as detailed in the Appendix, encompasses nine productive activities (agriculture, mining, electricity, energy, construction, industry, transport, services and informal sector) and four institutions (households, government, firms and rest of the world).

The equations linking economic variables follow an internal logic that is fairly standard to CGE modelling in developing countries (for an overview, see Bourguignon et al., 1989). On the supply side, formal activities maximize profit by combining fixed capital with labour factors (Eq. 1–3). The products may be sold locally or to the rest of the world (Eq. 6–9) and are imperfectly substitutable with imported products (Eq. 10–13). Primary incomes are distributed to different agents on the basis of their factor endowments and access to transfer and foreign incomes (Eq. 14–28). On the demand side, household consumption should be a linear expenditure system function; nominal demand from the government is assumed to be exogenous (Eq. 29–31). Intermediate consumption is driven by a fixed technical coefficient in each production process. The volume of investment demand (CDM and others) is assumed to be exogenous (Eq. 32–34). Prices, nominal investments, and row saving ensure the closure mechanisms for product markets, the capital market, and the external accounts market, respectively (Eq. 37–40). The closure rule for the labour market reflects the dualistic nature of the Mexican economy, as is characteristic of this developing country. Because labour supply is fixed in volume and real wages are rigid, the labour market balance can be achieved only through the informal sector, which serves as a shelter for workers excluded from formal employment and unprotected by an efficient social insurance system (Eq. 35–36). In that context, workers who are not employed in formal activities create individual, non-capitalistic microenterprises (Eq. 4–5), whose products sell only in domestic markets for final household consumption (Eq. 30).

Some additional equations link previous economics variables to some environmental variables. Their logic follows the conceptual framework of the international System of Environmental and Economic Accounting (SEEA). Three environmental costs are then be associated with the production of each activity: Depletion costs represent the monetary

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3 In 2012, the United Nations decided to adopt an integrated SEEA as an initial version of an international standard for Environmental and Economic Accounting (European Commission et al., 2012).
valuation of the depreciation of natural resources used in the production process,\(^4\) whereas 

*degradation costs* are monetary assessments of the restoration of the environmental damages 
caused by each economic activity.\(^5\) Each cost is assumed to be proportional to the volume of 
production of each activity (Eq. 45–46). Subtracted from the value added of each activity, 
these two types of environmental costs indicate the ecological gross domestic product or 
Green GDP (Boyd, 2007) of the Mexican economy (Eq. 43–44).

**Model databases**

Most of parameters in the economic equations and the initial level of the variables 
were calibrated from Mexico’s 2004 Social Accounting Matrix (2004-SAM), as built by 
Barboza-Carrasco et al. (2009). This 2004-SAM was previously adjusted to the needs and objectives of our analysis. First, the number of activities was reduced, to fit those used in the SEEA environmental accounting. Second, considering the nature of the CDM projects, an energy sector (*Energy*) was isolated to specify fossil energies (gas, oil, coal) responsible for emissions of greenhouse gas, which are the main target of CDM projects in Mexico. Third, because of the closure rule on the labour market in the model, an informal sector was included in the SAM using data from Mexican employment surveys (INEGI, 2006), to support the estimation of informal activities’ contributions to employment and value added.\(^6\)

The initial levels for the environmental variables and parameters came from the Mexican Environmental Accounts System (INEGI, 2010). For Mexico, the depletion costs mainly refer to hydrocarbons, forest resources, and underground water; degradation costs involve the pollution of water, air, and soil. For 2005–2009, these costs accounted for an average of 8% of Mexico’s GDP: 6% for degradation costs and 2% for depletion costs (INEGI, 2010).

\(^4\) This valuation relies on a market value approach, which covers only natural assets with economic value. These assets are connected with actual or potential market transactions (United Nations, 2000). Various methods exist to estimate the market value of the stocks of scarce natural resources (e.g., net present value of natural resources, net price method, user cost allowance).

\(^5\) This more difficult valuation relies mainly on the maintenance cost valuation method (i.e., estimate of the costs of restoration of an environmental asset to its original or a tolerable level of degradation) and the contingent valuation method of environmental services.

\(^6\) We use here a restricted definition of informal employment, corresponding to individual entrepreneurs and suppose that these informal microentrepreneurs receive the full value added that they generate.
2. Baseline scenarios of the impact of CDM Investments in Mexico

Exogenous foreign CDM investments \( \left( CDMQ_i \right) \) constituted the main variables for our simulations. We predict two impacts on the Mexican economy. First, they generate a demand shock for the activities which produce the fixed capital goods required for their implementation. Second, they generate a supply shock that changes the nature of the production process of some activities. We deduced the nature and the level of these shocks from the data of each Project Design Document (PDD) \(^7\) detailed in the CDM pipeline (Fenhann, 2013), supplemented by data from the UNFCCC (2012) about the type, location, amount, and stage of completion of each project. These data confirm the importance of CDM investments in Mexico since 2005 (Table 1).

| TABLE 1. CDM projects: Investments (in million USD) and installed electrical capacity (MW) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Registered | At Validation | Total |
| Number of Projects | Investment | Installed Electric Capacity | Number of Projects | Investment | Installed Electric Capacity | Number of Projects | Investment | Installed Electric Capacity |
| Type |
| Biomass energy | 6 | 30.9 | 0.3 | 9 | 45.8 | 100.0 | 15 | 76.7 | 100.3 |
| Coal bed/Mine methane | - | - | - | 1 | 12.3 | 7.0 | 1 | 12.3 | 7.0 |
| EE industry | 4 | 1.8 | 36.2 | 2 | 1.4 | - | 6 | 3.2 | 36.2 |
| EE own generation | 1 | 43.9 | - | 1 | 3.2 | - | 2 | 47.1 | - |
| Fossil fuel switch | - | - | - | 1 | - | - | 1 | - | - |
| Fugitive | 1 | 14.5 | - | 1 | 98.9 | 50.0 | 1 | 98.9 | 50.0 |
| Geothermal | - | - | - | 1 | 98.9 | 50.0 | 1 | 98.9 | 50.0 |
| HFCs | 1 | - | - | 1 | - | - | 1 | - | - |
| Hydro | 5 | 141.1 | 92.8 | 6 | 849.8 | 1071.0 | 11 | 990.9 | 1163.8 |
| Landfill gas | 23 | 90.8 | 69.2 | 10 | 43.5 | 30.3 | 33 | 134.3 | 99.5 |
| Methane avoidance | 98 | 21.5 | 5.9 | 5 | 59.0 | 3.7 | 103 | 80.5 | 9.6 |
| N2O | 1 | 0.3 | - | 2 | - | - | 3 | 0.3 | - |
| Transport | 5 | 3713.3 | - | 1 | 22.2 | - | 6 | 3735.5 | - |
| Wind | 26 | 7474.0 | 3937.9 | 5 | 874.8 | 495.8 | 31 | 8348.8 | 4433.7 |
| Total | 171 | 11532.1 | 4142.3 | 44 | 2010.9 | 1757.8 | 215 | 13543.0 | 5900.1 |

Notes: At Validation projects include those waiting for validation and those that have requested registration already. EE = energy efficiency. MW = megawatts of electric capacity.
Source: CDM pipeline 04/2013

\(^7\)Any submission of a CDM project requires such PDD, which provides information about the project’s legislative aspects, implementation, baseline scenarios adopted, funding sources, and involved local political operators.
A first group of 171 projects “registered”, such that they already have been validated by the Executive Board supervising the Kyoto Protocol’s CDM, represent US$11532.1 million (or nearly 1.25% of Mexico’s GDP). A second group of 44 projects still “at validation stage”, such that they are waiting to be validated, account for US$2010.9 million, or nearly 0.22% of Mexico’s GDP. Projects involving methane avoidance are the most numerous, but the data also reveal a preponderance of wind, hydro and transport projects—that is, 98.2% of registered and 87% of at validation investments. These projects, and renewable energy projects more generally (e.g., wind, hydro), appear to offer a sustainable alternative to the highly polluting thermal generation of electricity, which currently accounts for nearly 71% of installed electricity capacity in Mexico (SENER, 2010).

In this context, we consider two main scenarios for our simulations, either involving just registered projects or including projects that remain to be validated. We first apply these two scenarios to all types of CDM projects in Mexico, then, second, we consider only the renewable energy projects, which are critical for overall CDM investments. The four numerical simulations performed with our CGE model are summarized in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>All CDM Projects</th>
<th>Only Renewable Energy CDM Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scenario 1</td>
<td>Scenario 2</td>
</tr>
<tr>
<td></td>
<td>Registered</td>
<td>Registered and At Validation</td>
</tr>
<tr>
<td>projects</td>
<td>projects</td>
<td>projects</td>
</tr>
<tr>
<td>Demand shock for activities (million USD)</td>
<td>+ 6808,5</td>
<td>+ 7777,9</td>
</tr>
<tr>
<td>Industry</td>
<td>+ 390,2</td>
<td>+ 493,2</td>
</tr>
<tr>
<td>Transport</td>
<td>+ 3217,1</td>
<td>+ 3948,6</td>
</tr>
<tr>
<td>Construction</td>
<td>+ 1116,6</td>
<td>+ 1323,3</td>
</tr>
<tr>
<td>Total</td>
<td>+ 11532,1</td>
<td>+ 13543,0</td>
</tr>
<tr>
<td>Supply shock</td>
<td>$\alpha_{\text{ener,elec}}$</td>
<td>- 8,1%</td>
</tr>
<tr>
<td>Environmental shock</td>
<td>$\theta_{\text{elec}}$</td>
<td>- 8,1%</td>
</tr>
</tbody>
</table>

Source: Own calculations, based on CDM pipeline 04/2013.
The simulations differ by the magnitudes of the shocks experienced by the Mexican economy. On the demand side, we can determine this shock by analysing the PDD of each project and thereby uncovering the average distribution of fixed capital demand addressed to each activity. Wind, hydro, and transport\(^8\) projects largely determine this allocation. For example, for a wind project, 64% of investments go to \textit{industry} (e.g., purchase of wind turbines), 24% to \textit{construction} (engineering and electrical installations), 9% to \textit{services} (e.g., legal fees, project engineering, control systems, financial and import costs), and 3% to \textit{transport} (transportation costs). On the supply side, because of the type of investments in CDM projects, we assume that the production of energy and electricity would be the main concerns. The CDM pipeline shows that the additional production of electricity expected from all registered CDM projects would be nearly 8.1% (4142 MW) of the 2004 total production (EIA, 2004),\(^9\) whereas that expectation would increase to 11.5% (5881 MW) if we included at validation stage projects too. For solely renewable energy projects, the additional production obtained through registered projects would be 7.9% (4040MW), and that of the combined registered and at validation stage projects would be 11.0% (5625 MW). Relying on the principle of additionality from the Kyoto Protocol,\(^{10}\) we assume the generation of this clean electricity will replace the use of fossil fuels and reduce the demand for intermediate consumption of electricity activity in the production of energy. The effect of this environmentally friendly technology therefore needs to be included in each simulation, as a reduction of the technical coefficient \(ica_{\text{ener, elec}}\) for the electricity activity (Eqs. 3 and 32). It also should appear in the environmental equations, as a reduction of the same magnitude in the parameters linking depletion costs (\(\theta p_{\text{elec}}\)) and degradation costs (\(\theta g_{\text{elec}}\)) to the volume of production of electricity activity (Eqs. 45–46).

3. Simulations results

Table 3 describes the contribution of each industry to GDP and Green GDP, as well as to each environmental cost, at the initial equilibrium.

\(^8\) Branch allocation for transport projects is more difficult to estimate, because of the importance of the Metro Line 12 (Mexico City) and Metrotus 2-1 projects, which together account for an estimated total investment of US$3.4 billion.

\(^9\) We used the 2004 Mexican electricity sector data for two reasons: to maintain consistency with SAM-2004 and to avoid double counting of the impact of CDM in this sector during 2004–2012.

\(^{10}\) This principle states that the projects would not have happened in the absence of the CDM and that the new power capacity related to CDM projects substitutes for fossil fuels (greenhouse gas reduction).
TABLE 3. Economic and environmental contributions of each activity at initial equilibrium (share in %)

<table>
<thead>
<tr>
<th>Activity</th>
<th>GDP</th>
<th>Depletion Costs</th>
<th>Degradation Costs</th>
<th>Green GDP</th>
<th>Total Costs/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>4.0</td>
<td>26.9</td>
<td>18.9</td>
<td>2.5</td>
<td>38.8</td>
</tr>
<tr>
<td>Mining</td>
<td>3.6</td>
<td>71.4</td>
<td>0.2</td>
<td>1.9</td>
<td>44.2</td>
</tr>
<tr>
<td>Industry</td>
<td>17.2</td>
<td>1.0</td>
<td>2.9</td>
<td>16.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.3</td>
<td>-</td>
<td>1.4</td>
<td>1.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Construction</td>
<td>5.2</td>
<td>0.2</td>
<td>0.2</td>
<td>5.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Transport</td>
<td>8.3</td>
<td>-</td>
<td>49.9</td>
<td>6.1</td>
<td>30.6</td>
</tr>
<tr>
<td>Services</td>
<td>59.8</td>
<td>0.6</td>
<td>26.4</td>
<td>65.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Energy</td>
<td>0.6</td>
<td>0.0</td>
<td>0.2</td>
<td>0.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

| Total economy | 100.0 | 100.0 | 100.0 | 100.0 | 7.3 |

Source: Own calculations, based on INEGI (2010).

Nearly 60% of the Mexican national value added is generated by the service sector, and 17% by industry. Depletion costs come mainly from agriculture and mining, whereas the degradation costs are generated by the transportation sector, services, and agriculture. Globally, these environmental costs represent 7.3% of GDP.

In turn, Table 4 indicates the impact of Mexican CDM projects on each sector. Panel a (Panel b) details the impact of all type of projects (only renewable energy projects) for each scenario. According to these simulations, CDM investments contribute significantly to Mexican economic growth, mainly through a demand effect for activities. With all registered projects, GDP increases by 0.5%, an effect that gets logically amplified when we include validation projects too (0.7%). Renewable energy projects contribute to 0.4% of the growth in the first scenario and 0.5% in the second. In addition, the overall environmental impact of this economic growth appears negative or, at best, neutral, regardless of the simulations considered. When we take all types of projects into account, Green GDP grows at a slower pace than economic growth in both the first (0.4% vs. 0.5%) and the second (0.7%) scenarios. This negative impact reflects that growth is accompanied by parallel increases of depletion costs (3.0% in the first scenario, 4.0% in the second) and degradation costs (0.5% in both scenarios). Ultimately, the share of GDP represented by these environmental costs increases by 0.8% for both scenarios. These trends are confirmed in the data involving only renewable energy projects, though the magnitude of changes is less. In this case, Green GDP increases by 0.3% in the first scenario and 0.4% in the second. The depletion costs increase by 1.9%
(2.6%) in the first (second) scenario, while the degradation costs increase by 0.2% (0.3%), and their total share of the GDP increases to 0.4% (0.5%).

These global effects hide the sectoral changes that CDM investments generate for the economy though. With its close links with other sectors and the nature of its related projects, the electricity sector is logically the one most affected by the shocks. When we take all types of projects into account, its value added grows by 9.7% in the first scenario (38.3% in the second). At this stage, the supply effects in the model (i.e., reduced use of fossil fuels and associated effects on the degradation costs generated by electricity activity) exert a substantial influence. Despite increasing production, environmental costs decrease by -5.7% in scenario 1 and increase only slightly by 1.3% in scenario 2. The share of environmental costs from the electricity sector, as a proportion of total GDP, decreases by -14.1% (-26.7%) in the first (second) scenario. These results are confirmed by the analysis of renewable energy projects, in which case the contribution to GDP of the electricity sector rises by 18.9% (26.6%) in the first (second) scenario and generates lower degradation costs of -1.0% (-2.0%). Finally, we find a decrease in the share of environmental degradation in GDP from the electric sector (-16.8% and -22.6%).

**TABLE 4. Economic and environmental impacts of CDM investments in Mexico**

<table>
<thead>
<tr>
<th>Scenario 1: Registered projects</th>
<th>Agriculture</th>
<th>Mining</th>
<th>Industry</th>
<th>Electricity</th>
<th>Construction</th>
<th>Transport</th>
<th>Services</th>
<th>Energy</th>
<th>Total economy</th>
<th>GDP</th>
<th>Depletion Costs</th>
<th>Degradation Costs</th>
<th>Green GDP</th>
<th>Total Costs/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registered projects</td>
<td>1.0</td>
<td>4.3</td>
<td>0.8</td>
<td>9.7</td>
<td>-3.3</td>
<td>0.8</td>
<td>0.3</td>
<td>-1.7</td>
<td>0.5</td>
<td>3.0</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Registered and At validation projects</td>
<td>-0.2</td>
<td>6.1</td>
<td>1.0</td>
<td>38.3</td>
<td>-4.8</td>
<td>0.8</td>
<td>0.0</td>
<td>-1.2</td>
<td>0.7</td>
<td>4.0</td>
<td>0.0</td>
<td>0.2</td>
<td>-0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Mining</td>
<td>0.9</td>
<td>3.9</td>
<td>0.6</td>
<td>-5.7</td>
<td>-3.0</td>
<td>-0.7</td>
<td>0.3</td>
<td>1.5</td>
<td>-0.4</td>
<td>0.5</td>
<td>5.6</td>
<td>5.6</td>
<td>6.6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Industry</td>
<td>-0.9</td>
<td>3.9</td>
<td>0.6</td>
<td>-5.7</td>
<td>-3.0</td>
<td>0.7</td>
<td>0.3</td>
<td>1.5</td>
<td>-0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>1.0</td>
<td>-0.3</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.1</td>
<td>-</td>
<td>-0.7</td>
<td>1.3</td>
<td>40.4</td>
<td>-4.6</td>
<td>-4.6</td>
<td>2.7</td>
<td>-0.4</td>
<td>0.4</td>
<td>-4.6</td>
<td>-4.6</td>
<td>40.4</td>
<td>-26.7</td>
</tr>
<tr>
<td>Construction</td>
<td>-3.3</td>
<td>-3.0</td>
<td>-3.0</td>
<td>-3.3</td>
<td>-3.3</td>
<td>-0.7</td>
<td>0.3</td>
<td>-1.8</td>
<td>-0.4</td>
<td>0.8</td>
<td>-4.6</td>
<td>-4.6</td>
<td>40.4</td>
<td>-26.7</td>
</tr>
<tr>
<td>Transport</td>
<td>0.8</td>
<td>-</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
<td>-0.7</td>
<td>0.1</td>
<td>0.2</td>
<td>-0.4</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Services</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>-0.7</td>
<td>0.1</td>
<td>0.2</td>
<td>-0.4</td>
<td>0.6</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Energy</td>
<td>-1.2</td>
<td>2.7</td>
<td>2.7</td>
<td>-1.2</td>
<td>3.9</td>
<td>-1.2</td>
<td>3.9</td>
<td>-1.2</td>
<td>-0.4</td>
<td>0.8</td>
<td>-4.6</td>
<td>-4.6</td>
<td>40.4</td>
<td>-26.7</td>
</tr>
</tbody>
</table>

**Total economy**

- Scenario 1: Registered projects
  - Agriculture: 0.5
  - Mining: 3.0
  - Industry: 0.5
  - Electricity: 0.4
  - Construction: 0.8
  - Transport: 0.7
  - Services: 0.3
  - Energy: 3.3

- Scenario 2: Registered and At validation projects
  - Agriculture: 0.7
  - Mining: 4.0
  - Industry: 0.5
  - Electricity: 0.6
  - Construction: 0.8
  - Transport: 0.2
  - Services: 0.1
  - Energy: 3.9

**Total economy**

- Scenario 1: Registered projects: 0.8
- Scenario 2: Registered and At validation projects: 0.8
b. Only Renewable energy CDM projects (variation of initial shares in %)

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Depletion Costs</th>
<th>Degradation Costs</th>
<th>Green GDP</th>
<th>Total Costs/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario 1:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registered projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>-0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>-0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Mining</td>
<td>3.0</td>
<td>2.7</td>
<td>2.7</td>
<td>3.2</td>
<td>-0.3</td>
</tr>
<tr>
<td>Industry</td>
<td>0.6</td>
<td>0.4</td>
<td>0.4</td>
<td>0.6</td>
<td>-0.2</td>
</tr>
<tr>
<td>Electricity</td>
<td>18.9</td>
<td>-</td>
<td>-1.0</td>
<td>20.1</td>
<td>-16.8</td>
</tr>
<tr>
<td>Construction</td>
<td>-2.5</td>
<td>-2.4</td>
<td>-2.4</td>
<td>-2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Transport</td>
<td>0.4</td>
<td>-</td>
<td>0.3</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Services</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Energy</td>
<td>-0.3</td>
<td>1.6</td>
<td>1.6</td>
<td>-0.3</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Total economy</strong></td>
<td>0.4</td>
<td>1.9</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
</tr>
</tbody>
</table>

| **Scenario 2:**     |      |                 |                   |           |                 |
| Registered and At   |      |                 |                   |           |                 |
| validation projects |      |                 |                   |           |                 |
| Agriculture         | -0.2 | 0.0             | 0.0               | -0.3      | 0.2             |
| Mining              | 4.0  | 3.6             | 3.6               | 4.2       | -0.3            |
| Industry            | 0.7  | 0.5             | 0.5               | 0.7       | -0.2            |
| Electricity         | 26.6 | -               | -2.0              | 28.2      | -22.6           |
| Construction        | -3.3 | -3.2            | -3.2              | -3.3      | 0.2             |
| Transport           | 0.5  | -               | 0.5               | 0.6       | -0.1            |
| Services            | 0.0  | 0.2             | 0.2               | 0.1       | 0.1             |
| Energy              | -0.8 | 1.9             | 1.9               | -0.8      | 2.6             |
| **Total economy**   | 0.5  | 2.6             | 0.3               | 0.4       | 0.5             |

Source: Own calculations, using GAMS software.

With regard to other activities, our results show that the variations of sectoral production induced by CDM investments modify their respective contributions to the environment. They help slightly reduce the environmental impacts generated by mining, transportation, and industry, across the various simulations performed. In contrast, construction, services, and energy sectors exert a stronger environmental impact.

4. Conclusion

This study has explored the ex-post quantitative impact of CDM investments on the Mexican economy since 2004, using a CGE model that includes environmental topics as well. The numerical simulations show that these investments partially meet their development and environmental objectives. They also reveal the growth potential and the important fund for development represented by the CDM. However, its environmental impact appears broadly mixed, even though some sectors benefit from these “clean” investment flows—including electricity, the main target of CDM projects in Mexico.
In terms of our methodological perspective, these results require added nuance, because of the global approach we adopted, yet the nature of the data we used and the constraints imposed by current environmental accounting tools suggest that they offer a viable alternative to existing assessments of the effects of CDM on host countries. Further research could pursue an even more integrated approach, combining simultaneously a genuine sectoral analysis of the production processes affected by CDM investments together with global macroeconomic and environmental approaches.

References


European Commission, Food and Agriculture Organisation, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations, World Bank


APPENDIX: CGE Model

Formal activities or products: $i$ or $j$ = Agriculture, Mining, Electricity, Energy, Construction, Industry, Transport, Services

Informal activities or products: inf = Informal sector

Institutions: H=Households, G=Government, R = Rest of the World, F=Firms

Production Block

Formal production process

\[
QX_i = \begin{bmatrix} \alpha_F PVA_i \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right] \end{bmatrix}^{\frac{1}{\gamma}} - \left( 1 - \alpha_F \right) K_i^{\frac{1}{\gamma}} + \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right] \]

Informal production process

\[
QX_{inf} = \sum_{j} PVA_{j,inf,i} \gamma \]

Trade Block

Exports and domestic sales (CET specification)

\[
QD_i = \begin{bmatrix} \alpha_F PVA_i \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right] \end{bmatrix}^{\frac{1}{\gamma}} - \left( 1 - \alpha_F \right) LD_i^{\frac{1}{\gamma}} + \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right] \]

Imports and domestic sales (Armington specification)

\[
Q_i = A_i^{\frac{1}{\gamma}} \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right]^{\frac{1}{\gamma}} - \left( 1 - \alpha_i \right) LD_i^{\frac{1}{\gamma}} + \left[ \begin{array}{c} \sum_{j} PVA_{j,i} \gamma \end{array} \right] \]

Incomes and savings Block

Factors

\[
L = RL_{for} + RL_{inf} + RL_B
\]

Households

18. \[
YH = \lambda_{YH} RL + \lambda_{YH} RK + \text{Div}_F + \text{Trsf}_G + \text{Trsf}_R
\]

19. \[
YDH = (1 - t_H) \cdot YH
\]

20. \[
SH = mps \cdot YDH
\]

21. \[
CFMH = YDH - SH
\]

Firms

22. \[
YF = \lambda_{YF} RK + \text{Subv}_G
\]

23. \[
SF = (1 - t^*_F) \cdot YF - \text{Div}_F
\]

Administration

24. \[
YG = \text{TAX} + \text{TAXs} + \text{TAXX} + \lambda_G \cdot RK + \text{Trsf}_G
\]

25. \[
\text{TAXY} = t^*_H \cdot YH + t^*_F \cdot YF
\]

26. \[
\text{TAXS} = \sum_i \text{tax}_i \cdot P_{Q_i}\cdot Q_{Q_i}
\]

27. \[
\text{TAXX} = \sum_i \text{tax}_i \cdot P_{X_i}\cdot Q_{X_i}
\]

28. \[
SG = \text{TAX} - \text{TAXs} - \text{TAXX} - \text{Subv}_G
\]

Demand Block

Final Consumption

29. \[
PQ_i\cdot CFQH_i = \text{C min}_i \cdot PQ_i + \text{pmc}_i \cdot \left[ \text{CFMH} - \sum_j \text{C min}_j \cdot PQ_j - PD_{inf} \cdot CFQH_{inf} \right]
\]

30. \[
PD_{inf} \cdot CFQH_{inf} = \text{C min}_i \cdot PD_{inf} + \text{pmc}_{inf} \cdot \left[ \text{CFMH} - \sum_j \text{C min}_j \cdot PQ_j \right]
\]

31. \[
PQ_i \cdot CFQG_i = \varphi_i \cdot \text{CFMG}
\]

Intermediate consumption

13
32. \( DIQ = \sum_{i}^{\mathit{ica}_{ij}, QN_{ij}} + \mathit{ica}_{i,\text{int}} \cdot QD_{\text{int}} \)

**Investment**

33. \( IT = \sum_{i}^{\mathit{INVQ}_{i}, \mathit{PQ}_{i}} + \mathit{CDM} \)

34. \( CDM = \sum_{i}^{\mathit{CDMQ}_{i}, \mathit{PQ}_{i}} \)

**Closure rules**

**Labor market**

35. \( LDS = \sum_{i}^{LD_{i}, LD_{\text{int}}} \)

36. \( w = \overline{w} \)

**Commodities**

37. \( QQ_{i} = \mathit{CFQH}_{i} + \mathit{CFQG}_{i} + \mathit{DIQ}_{i} + \mathit{INVQ}_{i} + \mathit{CDMQ}_{i} \)

38. \( QD_{\text{int}} = \mathit{CFQH}_{\text{int}} \)

**Foreign account**

39. \( \sum_{i}^{\mathit{EXR}, \mathit{PWM}_{i}, QM_{i}} = \sum_{i}^{\mathit{EXR}, \mathit{PWE}_{i}, QE_{i}} + RL_{R} + Trsf_{G} + Trsf_{H} + Srow \)

**Capital**

40. \( IT = SF + SH + SG + Srow \)

**Price index and numerar**

41. \( Pindex = \sum_{i}^{\pi_{i}, \mathit{PQ}_{i}} \)

42. \( \mathit{EXR} = 1 \)

**Environmental topics**

43. \( \mathit{GDP} = \sum_{i}^{\mathit{PVA}_{i}, QX_{i}} \)

44. \( \mathit{GreenGDP} = \mathit{PB} - \sum_{i}^{\mathit{DEGC}_{i}} - \sum_{i}^{\mathit{DEPC}_{i}} \)

45. \( \mathit{DEGC}_{i} = \mathit{\Phi}_{i}, QX_{i} \)

46. \( \mathit{DEPC}_{i} = \mathit{\Phi}_{i}, QX_{i} \)

**Simulations impacts on parameters**

\[ \theta_{i} = \overline{\theta}_{i} \quad \forall i \neq \text{elec} \]

\[ \theta_{\text{elec}} = (1 - \mathit{cdm}_{\text{effect}}) \cdot \overline{\theta}_{\text{elec}} \]

\[ \mathit{ica}_{ij} = \mathit{ica}_{0_{ij}} \quad \forall i \neq \text{elec} \]

\[ \mathit{ica}_{\text{ener.elec}} = (1 - \mathit{cdm}_{\text{effect}}) \cdot \overline{\mathit{ica}}_{0_{\text{ener.elec}}} \]

**Simulation of the impact of All type of CDM projects**

Sc.1: \( \mathit{cdm}_{\text{effect}} = 0.081 \)

Sc.2: \( \mathit{cdm}_{\text{effect}} = 0.115 \)

**Simulation of the impact of renewable Energy CDM projects**

Sc.1: \( \mathit{cdm}_{\text{effect}} = 0.079 \)

Sc.2: \( \mathit{cdm}_{\text{effect}} = 0.11 \)

**Endogenous variables**

- \( \mathit{PVA} \): Value-added activity price
- \( \mathit{PVA}_{\text{int}} \): Informal value-added activity price
- \( \mathit{PX}_{i} \): Aggregate producer commodities price
- \( \mathit{PD}_{i} \): Domestic commodities price
- \( \mathit{PD}_{\text{int}} \): Informal commodities price
- \( \mathit{PE}_{i} \): Export commodities price
- \( \mathit{PM}_{i} \): Import commodities price
- \( \mathit{PQ}_{i} \): Composite commodities price
- \( \mathit{Pindex} \): Consumer price index
- \( \mathit{EXR} \): Exchange rate
- \( \mathit{QX}_{i} \): Quantity of aggregate commodity i output
- \( \mathit{QD}_{i} \): Quantity of domestic supply of commodity i
- \( \mathit{QD}_{\text{int}} \): Quantity of supply of informal commodity
- \( \mathit{QE}_{i} \): Quantity of commodity i exports
- \( \mathit{QM}_{i} \): Quantity of commodity i imports
- \( \mathit{QQ}_{i} \): Quantity of composite commodity i
- \( \mathit{CFQH}_{i} \): Quantity of consumption of composite commodity i by households
- \( \mathit{CFQH}_{\text{int}} \): Quantity of consumption of informal commodity by households
- \( \mathit{CFQG} \): Quantity of consumption of composite commodity i by Government
- \( \mathit{DIQ}_{i} \): Quantity of intermediate demand for composite commodity i
- \( \mathit{RL} \): Labour incomes
- \( \mathit{RL}_{\text{for}} \): Labour incomes from formal activities
- \( \mathit{RL}_{\text{int}} \): Labour incomes from informal activities
- \( \mathit{RK} \): Capital incomes
YH
Households’ income

YDH
Households’ disposable income

SH
Households’ savings

CFMH
Households’ consumption expenditures

YF
Firms’ income

SF
Firms’ savings

YG
Government’s income

TAXY
Income tax

TAXs
Sale tax

SG
Government’s savings

Srow
Foreign savings

Exogenous variables

CFG
Government consumption expenditures

HTrsf
Transfers from government to households

GSubv
Transfers from government to firms

DivF
Dividends from firms to households

R
Transfers from rest of the world to households

PWE
Foreign export commodities price

PMW
Foreign import price

KI
Quantity of capital factor in activity i

w
Labour wage rate

Parameters

A
Production function efficiency

A
Production function share parameter for commodity i

α
Production function share parameter for commodity i

μ
Production function exponent for commodity i

σ
Production function substitution parameter for commodity i

i
Quantity of intermediate input i per unit of product j

A
Armington function shift parameter for commodity i

A
Armington function share parameter for commodity i

μ
Armington function exponent for commodity i

σ
Armington function substitution parameter for commodity i

A
CET domestic-export function shift parameter for commodity i

A
CET domestic-export function share parameter for commodity i

κ
CET domestic-export function exponent for commodity i

CDM
Nominal CDM investment

IT
Nominal investment

LD
Quantity of labour in activity i

LDi
Quantity of informal labour

wi
Labour wage rate in activity i

GDP
Gross domestic product

GreenGDP
Green gross domestic product

DEGC
Degradation costs from activity i

DEPC
Depletion costs from activity i

INQ
Quantity of investment demand for composite commodity i

CDMQ
Quantity of CDM investment demand for composite commodity i

RL
Labour income from rest of the world

RK
Capital income from rest of the world

LDS
Quantity supplied of labour factor

QNG
Quantity of government consumption of non marketed commodities

Subv
Price subvention of public health commodities

σ
CET domestic-export function substitution parameter for commodity i

τa
Sales tax rate for commodity i

τt
Production tax rate for commodity i

τh
Direct tax rate on households

τf
Direct tax rate on Firms

c
Subsistence consumption of commodity i for households

c
Subsistence consumption of informal commodity for households

pmc
Marginal share of consumption of spending on commodity i for households

pmc
Marginal share of consumption spending on informal commodity for households

φ
Share of commodity i in total government consumption

mps
Marginal propensity to save for households

π
Weight of commodity i in the consumer price index