Do clean development mechanisms promote sustainable development in Brazil? a cross-sectoral investigation

Sara Gurfinkel M. Godoy
Universidade Federal do Pará, Belém, Brazil
Maria Sylvia Macchione Saes
*Department of Business Administration, Universidade de São Paulo,
São Paulo, Brazil*
Paula Sarita Bigio Schnaider
Department of Administração, Universidade de São Paulo, São Paulo, Brazil, and
Roberta Castro Souza Piao
Department of Production Engineering, Universidade de São Paulo, São Paulo, Brazil

Abstract

Purpose – This paper intends to verify the extent to which Clean Development Mechanism (CDM) projects intend to contribute to sustainable development (SD) in Brazil, one of the top three leading countries in terms of the number of CDM projects. The authors assess the impact of CDMs not only in environmental aspects, but also social and economic ones.

Design/methodology/approach – The authors define a set of qualitative sustainability indicators and scrutinize documents regarding a sample of almost half of all the projects registered in Brazil between 2004 and 2020 (219 projects).

Findings – The findings of this study contradict many previous studies finding very limited evidence of SD in CDMs in many different countries: most projects in Brazil intend to contribute to some extent with SD, with 91% and 75% claiming to improve social and economic aspects, respectively.

Practical implications – The authors derive lessons from Brazil that can be used in other researches.

Social implications – The authors derive lessons from Brazil and propose paths for public policy toward encouraging sustainable development.

Originality/value – The empirical data set relies on data collected directly from each of the projects in Brazil (roughly half of all of them) between 2004 and 2020. This is not only up to date, but pushes further the analytical scope of previous works.

Keywords Clean development mechanism, Sustainable development, Greenhouse gas emission

Paper type Research paper

1. Introduction

Since the Kyoto Protocol in 1997, a number of instruments have been established in order to help developed countries fulfilling their goals in terms of reducing their combined greenhouse gases (GHG) emissions (Michaelowa, Shishlov, & Brescia, 2019; UNFCCC, 2011).

Clean Development Mechanism (CDM) is one of these instruments, accumulating a total of over 4,000 projects worldwide. It consists of a way to allow developed nations to carry out sustainable projects in developing countries, so that the GHG emissions reduction generated by these projects is accounted toward the developed country's emission goals – one of the so-called Flexibility Mechanisms. With this instrument, the actual reduction outcomes in developing countries obtain equivalence in carbon credits to be used by developed nations that had emission reduction targets (Lopes, 2002; Franguetto & Gazani, 2002; Pereira, 2002).

An interesting issue about CDMs is that they should go way beyond reducing GHG emissions, encouraging sustainable development (SD) in a much broader way. Each country is free to create its own specific rules. Brazil, for instance, who brought the very first CDM project registration worldwide, requires these projects to specify how they intend to contribute to income generation, job creation, technological development, regional integration and articulation with other sectors. It is worth noting that CDMs are not legally required to satisfy all these criteria, but they must mention which contributions they intend to make. Nonetheless, Brazil ranks among the top three countries in number of CDMs: 463 projects have been registered between 2004 and 2020, representing 4% of all projects being developed worldwide (Unep Risoe, 2020).

Given this scenario, in this paper we seek to verify the extent to which these projects intend to contribute to sustainable development (SD) in Brazil, considering a broader definition of SD as environmental, social and economic aspects (Brundtland, 1987; Olsen & Fenhann, 2008). Specifically, we seek to identify which activities contribute the most to SD, i.e. which sectors are more or less beneficial and what is the specific impact of the projects conducted in each sector on SD in general; also, we aim at pinpointing the extent to which CDM projects intend to go beyond GHG emission reduction aspects.

To this end, we qualitatively analyze 219 projects representing 47% of total projects registered in Brazil from 2004 to 2020. Moreover, we were cautious to select a very diversified sample, including projects in different sectors throughout time. As far as we can tell, we are the first to scrutinize this number of diversified projects in Brazil. The analyses were based on "Annex III" reports, a qualitative information document filled out by the CDM proponents. This information was standardized and classified, with the purpose of comparing projects and sectors in Brazil (MCTIC, 2021). Based on our results, we derive lessons from Brazil and propose paths for public policy toward encouraging SD.

2. CDMs across different countries: what is the previous evidence on sustainable development?

A CDM is a voluntary program aiming to help developed countries that have emission reduction target to fulfill their goals by building projects in developing countries, while promoting local SD (UNFCCC, 2011; Mehling & Mielke, 2012; Shishlov & Bellassen, 2016).

As described in Article 12 of the Kyoto Protocol, in order to obtain a CDM project approval, in addition to the GHG emission reduction target, proponents should indicate measures linked to the SD of the place where the project would be implemented. However, as SD definitions are very subjective, with different interpretations, the Kyoto Protocol asks project proponents for a formal description of future activities related to SD (Dirix, Peeters, & Sterckx, 2016; Benites-Lazaro & Mello-Théry, 2017; UNFCCC, 2011). Thus, the CDM host country determines the particular rules, defining the meaning of SD. However, as definitions differ from country to country, UNFCCC proposes ways to guide these understandings (UNFCCC. United Nation Framework Climate Change, 2020).

There are several definitions regarding the SD concept, and there is no single global standard for them in terms of CDM projects. Because of different approaches Olsen and Fenhann (2008), claim that SD definition should be the same worldwide, with an international

standard for all CDMs. Nonetheless, the ideas considered by countries are based on the UN Brundtland Report, "Our Common Future" (Brundtland, 1987), which admits that a sustainable enterprise is one that simultaneously provides economic, social and environmental benefits. Thus, a country's development cannot be limited to social aspects and economic growth but must incorporate complex relationships between future societies and the environment (Elkington, 2004; Sachs, 2005).

A key question about CDMs is whether they are successfully promoting SD in host countries, and how SD can be encouraged. Previous literature indicates that the results of CDM projects in terms of SD in developing countries are not clear (Kim, 2004; Dirix *et al.*, 2016). Moreover, prior research indicates that less than 1% of global projects contribute to SD in developing countries (Sutter & Parreño, 2007). It also states that SD activities in developing countries can be significantly improved (Olsen & Fenhann, 2008) as they do not seem to substantially contribute, for instance, in reducing poverty in CDM host countries (Dirix *et al.*, 2016). Similarly, Siedenburg, Brown, and Hoch (2016) evaluated GHG emission reduction projects in Madagascar and Mali and concluded that the number of SD initiatives related to CDM has been low, with several obstacles to be overcome, particularly in rural areas. Perhaps the most important of these obstacles is the lack of a universal definition of SD.

Such a lack of SD definition has also dominated previous empirical literature, as each group of scholars tends not to focus on a single country, let alone Brazil, and also not emphasizing specific aspects, such as technological transfer, job, income and education generation. As each nation is free to set its own guidelines and requirements for SD, the concept becomes very subjective and ad-hoc, depending on each country's perceptions and needs. This is evident, for example, in the comparison of Brazilian and Peruvian hydroelectric projects as stated by Cole and Roberts (2011), indicating that the former's propositions regarding SD are more subjective than the latter's. In this sense, this paper proposes to analyze Brazil specificities related to SD in CDM projects.

Uddin, Blommerde, Taplin, and Laurence (2015) analyzed 30 Chinese projects focusing on methane reduction in coal mines and concluded that variables related to technology transfer stood out compared to others. Nonetheless, this is not always the case, as only 39% of all global CDMs encompass technology and/or knowledge transfer, and most of those are large-scale projects (Seres & Haites, 2008), importing technology namely from countries like Japan, Germany, USA, France and England (Dechezleprêtre, Glachant, & Ménière, 2009). As stated by Michaelowa *et al.* (2019), technology transfer depends on the CDM project activity, with some sectors being more dependent on foreign technology than others. This is the case described in Costa-Júnior, Pasini, and Andrade (2013), whereby technology import does not frequently occur in Brazil because most of the technology required for CDM it is locally developed.

Some other research studies focus on the contribution of CDM projects in terms of its ability to generate work and income or develop educational programs. This is the case of Olsen and Fenhann (2008), who advocate that "generation of work and income" is the aspect that contributes the most to SD in CDM projects, as this had been found in 68% of their analyzed projects. Benites-Lazaro and Mello-Théry (2017) find a very similar result in their dynamic panel analyses, although their aim was to assess the relationship between SD projects and their stakeholders, and not the particularities of SD in each of the CDM projects. In the same vein, Mori-Clement and Bednar-Friedl (2019) and Mori-Clement (2019) find that CDMs encourage income generation, while only those in the hydro sector contribute to reducing poverty at the municipal level in Brazil (Mori-Clement, 2019).

This diversity of understanding of SD definitions and lenses leads to a secondary issue: the lack of incentives for project proponents to promote local SD, primarily because of monitoring and enforcement deficiencies. The rationale here is that if very little is done to ensure that SD takes place within host countries, project proponents have little incentive to

promote it. This helps explaining why many CDM projects do not contribute satisfactorily to SD in host countries (Olsen & Fenhann, 2008; Olsen, Arens, & Mersmann, 2018). This is not surprising, after all, it is not easy to create an incentive system or enforcement mechanisms on something that is not unanimously well defined to begin with.

3. CDM requirements in Brazil

The very first CDM project to be registered worldwide was a Brazilian project, "Novagerar", a landfill company which promoted local SD through energy generation for schools and surrounding communities, back in 2004. This example has been followed in a rapidly growing number of projects ever since. To date, Brazil ranks among the top three countries in number of CDMs: 344 projects have been registered there between 2004 and 2020, representing 4% of all projects being developed worldwide (Unep Risoe, 2020).

As mentioned before, host country is free to set its own regulations toward SD implementation. In Brazil, these are described in a document named "Annex III". It contains detailed guidelines to describe how the project intends to contribute to local SD, promoting economic, environmental and social improvements, in line with Olsen and Fenhann (2008). These standards were defined by the Inter-ministerial Commission on Global Climate Change (CIMGC), through Resolution no. 01, 2003. These documents are made public through the website of the Ministry of Science, Technology and Innovation (MCTIC, 2020).

CDM proponents are required to fill out the guide in Annex III, in a highly qualitative manner, specifying how they intend to contribute to specific criteria (Table 1).

This provides preliminary evidence in favor of CDM projects developed in Brazil fulfilling SD in a broader way, not only in terms of environmental impacts. Nonetheless, the numerous works mentioned before raise questions about the effectiveness of these projects in practice since each proponent is free to choose which sustainability aspects to focus on. Hence, in the

Contribution criteria	Contribution details
Contribution to local environmental sustainability	Evaluates local environmental impact (solid waste, liquid effluents, air pollutants among others) provided by the project in comparison to local environmental impact estimated as the reference scenario
Contribution to the development of working conditions and net jobs generation	Evaluates the project's commitment to social and labor responsibilities, health and education programs and the civil rights defense. It also assesses the increase in the qualitative and quantitative jobs (direct and indirect) by comparing the project scenario to the reference scenario
Contribution to income distribution	It assesses the direct and indirect effects on the low-income population quality of life, observing the socioeconomic benefits provided by the project in comparison to the reference scenario
Contribution to training and technological development	It assesses the project's technological innovation compared to the reference scenario. It also assesses the possibility of reproducing the technology used in CDM, observing its demonstrative effect, as well as evaluating the origin of the equipment, the existence of royalties and technological licenses and the need for international technical assistance
Contribution to regional integration and articulation with other sectors	The contribution to regional development can be measured by the project integration with other socioeconomic activities in the region where it is implemented

Source(s): Adapted from MCTIC (2021)

Table 1.
Sustainable development criteria, Annex III

coming sections, we assess the extent to which CDM projects carried out in multiple sectors in Brazil intend to fulfill each of these requirements and play an active role in encouraging SD in that country.

4. Research design and methodology

This research is qualitative and exploratory, and relies on a collection of Brazilian CDM project reports, whose information is provided in "Annex III". These documents are available and dispersed throughout the Ministry of Science, Technology, Innovations and Communications website (MCTI, 2020; Unep Risoe, 2020; UNFCCC. United Nation Framework Climate Change, 2020).

Noteworthy, the information in "Annex III" is quite subjective, differing from firm to firm. Not all documents follow the same pattern and certain proponents only describe the environmental standards required by law, such as EIA/RIMA Brazilian environmental licenses. These environmental requirements do not belong in the scope of "Annex III", which should refer to what the company proposes in addition to the environmental effects, aiming at promoting SD.

Our population comprised 463 Brazilian projects approved under the CDM program between November, 2004 and January, 2020. Out of those, 219 reports were selected to be analyzed or 47% in total (Table 2).

In order to guide our choice, we sought to gather a representative sample, with a sufficient number of projects, and containing a considerable share of total projects by sector and by year [1]. We also had discretion to involve projects with different profiles, including a few unusual projects, which present innovative ideas, like power generation out of rice husks. It is worth noting that while some sectors counted only for one project, this proportion is in line with their representativeness in the general population. Table 3 below shows the breakdown of our selection by sector.

The methodology of this study is quite different compared to previous research, like those by Olsen and Fenhann (2008) and Benites-Lazaro and Mello-Théry (2017). First of all, the information in this work refers to a different period (November, 2004 to January, 2020).

| | Number of projects | | |
Year	Sample	Total projects	Share
2004	2	3	67%
2005	56	69	81%
2006	12	73	16%
2007	34	60	57%
2008	16	22	73%
2009	16	34	47%
2010	11	23	48%
2011	10	20	50%
2012	50	123	41%
2013	7	21	33%
2014	2	7	29%
2015	1	3	33%
2016	1	4	25%
2017	0	0	0%
2018	1	1	100%
2019	0	0	0%
Total	*219*	*463*	*47%*

Source(s): MCTIC (2020)

Table 2.
Brazilian projects analyzed, and projects approved at MCTIC

Additionally, it considers some diverse characteristics and details from earlier studies. Much of the existing literature evaluates countries in general and not Brazil specifically.

To guide our analyses, we took a series of steps. First, relying on Olsen and Fenhann (2008) and Olsen *et al.* (2018), we defined a number of indicators to classify SD in CDMs into environmental, social and economic aspects. We also added our own set of indicators, "independent criteria", to further dig into the impact of CDMs in Brazil, going beyond existing literature. All these indicators are shown in Table 4 below. It is worth noting that they do not intend to quantify SD, but to guide the collection of descriptive information from Annex III reports. In order to collect data, each Annex III report has been read by different authors of this paper, one by one, in order to identify the relevant information for our research. The criteria in Table 4 guided our data collection.

After collecting data according to the criteria laid out in Table 4, we summarized the information into Table 5, counting the number of projects satisfying each criterion and computing simple and weighted averages, both overall and per sector, per indicator. This will help build a general picture of our results.

Finally, we further dig into Annex III reports to gather qualitative and specific information to help explaining some of our results and identifying gaps and strengths in CDMs in Brazil. The Annex III information is qualitative, so each proponent is free to fill in the document in their own way, like PCH Cachoeirão describing job creation: "number of engineers, 25; archaeologists, 13".

5. Results: do CDMs intend to promote SD in Brazil?

As shown in Table 5, a general result of this study is that 46% of all analyzed projects claim to contribute satisfactorily to SD (weighted average of 52%, considering the number of projects per sector), although most of them do not clarify exactly how companies intend to get it done. Methane Avoidance projects, such as swine farming (72% of the projects), are the most explicit ones in terms of details, better describing what they actually intend to do in regards to SD. Despite limitation, our general result surprisingly contradicts some previous studies, which do not find enough evidence of SD in CDM host countries (Sutter & Parreño, 2007).

Sector-wise, as shown in Table 5, those accumulating the largest number of projects claiming to promote SD in Brazil are Biomass, Wind, Hydro, Methane Avoidance and Landfill Gas. It is worth mentioning that sectors such as the EE industry, NO_2 and Reforestation presented even greater averages (e.g. 82% for the EE industry), but their representativeness in terms of the absolute number of projects is very low, with some of these presenting only a single project. Our general and sector-wise figures are partially in line with Lazaro and Gremaud (2017), who state that it is not clear which sector contributes the most to SD. After all, the general picture we provide above indicates that while some sectors concentrate a larger number of projects than others, their respective impacts tend to be much lower than

Sector	# of projects	Sector	# of projects
Biomass energy	44	Landfill Gas	54
EE industry	1	Methane avoidance	36
EE services	7	N_2O	4
EE supply side	1	Own generation	1
Fossil fuel switch	8	PFCs + SF6	2
Fugitive	1	Reforestation	2
Hydro	33	Wind	25
Source(s): MCTIC (2020)			

Table 3.
Sectors analyzed, and number of CDM projects

Annex III premises	Indicator	General criteria of contribution (1)
Contribution to local environmental sustainability[1]	Social, Economic and Environmental	1- The project has actions directly related to SD (social, economic and environmental)
Contribution to working conditions development and net jobs generation	Social, Economic	2- The project contributes to working conditions improvement and net generation of jobs
Contribution to income distribution	Economic	3- The project contributes to income distribution
Contribution to training and technological development	Economic	4- The project contributes to training and technological development
Contribution to regional integration and articulation with other sectors	Social, Economic	5- The project contributes to regional integration and articulation with other sectors
		Specific criteria of contribution (2)
Contribution to local environmental sustainability	Environmental	6- Environmental contribution: incentive for sustainable planting, development of composting techniques and other extra activities related to GHG emissions reduction
Contribution to the development of working conditions and net generation of jobs	Social	7- Contribution to civil infrastructure: construction/restoration of facilities for local population benefit, such as schools, housing and church
	Social	8- Contribution to energy infrastructure, such as electricity distribution to the local population
	Social	9- Contribution to cultural infrastructure, such as resources for promoting culture
	Social	10- Contribution to health infrastructure, such as provision of medical and dental insurance for the population
	Social	11- Contribution to educational infrastructure, such as education courses creation related to sustainable practices within the community
	Economic	12- Contribution to financial infrastructure, such as direct transfer of financial resources, coming from carbon credits, for instance
	Economic	13- Contribution to the development of working conditions and net generation of jobs
	Economic	14- Contribution to the generation of direct and indirect jobs
	Economic	15- Contribution to income generation
Contribution to training and technological development	Economic	16- Contribution related to foreign technology or to develop local technology
		Independent criteria (3)
	Social, Economic and Environmental	17- The project has actions directly related to Sustainable Development in a general point of view
	Social, Economic and Environmental	18- The organization that has developed the project is new
	Social, Economic and Environmental	19- The organization was sustainable, before the elaboration of the project[2]

Note(s): [1] Despite the fact that the report places contribution in an environmental scope at "Contribution to local environmental sustainability", many proponents used this space to describe other actions, such as contribution to education, construction among others. Due to that, we included those characteristics, also in this topic
[2] The conclusion related to "consider the organization sustainable" were based on reports information, that is, if it was a company focused on sustainability even before the CDM Project have been developed

Table 4.
Sustainable development analysis criteria

Activity	Sector total	Proposes actions towards SD		Company was sustainable before CDM		Sustainability on top of GHG emission reduction		Contribution to local environmental sustainability		Contribution to working conditions development and net job generation		Direct employment generation		Indirect employment generation		Contribution to income generation		Contribution to regional integration and articulation with other sectors		Financial contribution to the local population through courses, etc		Use of foreign technology only		Average %
		Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	Qt	(%)	
Biomass energy	44	18	41%	18	41%	26	59%	38	86%	41	93%	42	95%	32	73%	30	68%	38	86%	29	66%	13	30%	67%
EE industry	1		0%		0%	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	1	100%	82%
EE services	7		0%	7	100%		0%		0%	7	100%	7	100%	7	100%		0%	7	100%		0%		0%	45%
EE supply side	1		0%		0%		0%		0%		0%		0%		0%		0%		0%		0%		0%	0%
Fossil fuel switch	8		0%	3	38%	3	38%	4	50%	5	63%	5	63%	3	38%	3	38%	4	50%	3	38%	2	33%	41%
Fugitive	1		0%		0%		0%		0%		0%		0%		0%		0%		0%		0%		0%	0%
Hydro	33	3	9%	2	6%	14	42%	17	52%	29	88%	33	100%	18	55%	21	64%	24	73%	18	55%	2	6%	50%
Landfill gas	54	4	7%	5	9%	24	44%	40	74%	50	93%	53	98%	15	28%	11	20%	33	61%	19	35%	20	37%	46%
Methane avoidance	36	1	3%	1	3%	26	72%	18	50%	35	97%	35	97%	11	31%	10	28%	28	78%	31	86%	2	6%	50%
N₂O	4	2	50%	1	25%	3	75%	3	75%	4	100%	4	100%	2	50%	2	50%	3	75%	3	75%	3	75%	68%
Own generation	1		0%		0%	1	100%		0%		0%	1	100%		0%		0%		0%	1	100%		0%	27%
PFCs + SF6	2		0%	1	50%	1	50%	1	50%	2	100%	2	100%	1	50%	1	50%	1	50%	1	50%	1	50%	50%
Reforestation	2	1	50%		0%	2	100%	2	100%	1	50%	2	100%	1	50%		0%	2	100%	2	100%		0%	64%
Wind	25	1	4%		0%	6	24%	10	40%	25	100%	25	100%	25	100%	15	60%	22	88%	11	44%	6	24%	53%
Average	219	30	12%	38	19%	107	50%	134	48%	200	70%	210	82%	116	48%	94	34%	163	62%	119	54%	50	26%	46%
Weighted average			14%		17%		49%		61%		91%		96%		53%		43%		74%		54%		23%	52%

Table 5.
Sustainable development criteria and CDM sector

those with fewer projects. But what matters most to SD? The number of projects promoting it
or their relative impact? What are the actions taken by each sector to promote SD?

In order to answer these questions, we must consider the specificities underlying the
general figures presented above. In this respect, the very first aspect that deserves to be
scrutinized is the proponent being sustainable before the CDM proposal. This indicates
whether CDMs encouraged firms toward SD or merely leveraged their previous SD efforts. In
this respect, the sectors of Methane Avoidance, Hydro and Landfill Gas presented the lowest
proportion of previously sustainable firms. At the same time, these sectors accumulated some
of the largest number of CDM projects (roughly 50% of our sample), nearing 50% on average
in terms of SD promotion. Preliminarily, this shows that CDMs have been very successful in
promoting SD within these industries. In the same vein, the EE industry and EE supply side
had no sustainable firms before CDMs, but ranked among the best ones in SD after the CDM
proposals. Nonetheless, as mentioned before, these sectors accumulated a very small number
of projects.

On the other hand, while Biomass projects added up to 20% of our sample, 41% of all firms
in this sector had already developed sustainable actions prior to their CDMs. This implies that
the average SD incidence (67% of CDMs) in this sector is not as representative as the cases of
aforementioned sectors.

This result does not imply that Biomass sector do not promote SD, but that almost half of
the projects were already prone to developing SD. Perhaps this explains why this industry is
the second one contributing the most to "sustainability on top of GHG emission reduction".
While 50% of all our sample claimed to promote "sustainability on top of GHG emission
reduction", the Biomass sector alone accounts for 22% out of those 50%. Among the projects
meeting this criterion, 60% come from Methane Avoidance, Landfill Gas and Hydro sectors,
while 10% come from Fossil Fuel Switch, NO_2, Reforestation and Wind. These results
preliminarily indicate that CDMs are somehow helping to promote SD in Brazil, in addition to
reducing GHG emissions – fulfilling the goals for which they have been conceived on the first
place. Nonetheless, in order to have a better picture of the extent to which these projects
contribute to SD in Brazil, and how they do it, all three dimensions of SD will be scrutinized.
This analysis is shown in the coming sections.

5.1 Environmental contribution (contribution to local environmental sustainability)
As a general result, 61% of our sample claimed to contribute to "local environmental
sustainability", as shown in Table 5, and this is the lowest percentage of all three SD
dimensions (environmental, social and economic). This is largely due to the fact that those
sectors contributing the most in terms of the total number of projects claim to contribute
between 50-75% to this dimension (Landfill Gas, Methane Avoidance and Hydro).
Nonetheless, except for EE service, EE supply side, own generation and Fugitive, with no
projects meeting this criterion, all sectors claimed to positively contribute. Biomass energy is
the one contributing the most in terms of number of projects, totaling 38 (with 86% SD). Other
sectors like the EE industry and Reforestation present one or two projects, 100% SD. This
means, once again, that those sectors contributing the most in this dimension accumulate the
smallest number of projects.

At the same time, we managed to observe what particular actions are intended by CDM
proponents in this respect. Many of these were entirely non-profit oriented, such as planting
trees or vegetable gardens. Nonetheless, a great deal of projects proposed actions that are
somehow profit-oriented, despite being sustainable. These include, for instance, compost
production or electricity generation from methane gas, burn for sale or own use. Other
examples fall "in between", as they somehow contribute to profitability, but not as directly as
the ones mentioned before. These include helping the population to learn efficient

management techniques in agricultural processes or teaching them how to implement selective waste collection.

5.2 Social contribution (contribution to working conditions, direct and indirect employment)
An interesting finding of our study is that CDMs in Brazil go way beyond environmental aspects. In fact, social indicators demonstrated the largest importance, since these projects presented the highest averages of SD for all sectors in our sample (as shown in Table 5). Overall, 91% of the CDMs claimed to contribute to working conditions and net job generation, and 96% declared direct employment generation. These results are consistent with Olsen and Fenhann (2008), but even more sensible.

What is most interesting about these findings is that 89% of the projects we analyzed are smaller scaled and intend to create jobs for up to 400 employees, whereas only 11% will hire over 400 people. Large-scale projects, such as SHPs and Wind Energy, hold the largest number of jobs, probably due to their dimensions, naturally demanding a bulkier number of professionals. On the other hand, although small-scale projects are more abundant in Brazil, they are the ones that employ a smaller number of direct employees. There are fewer employees in the Landfill, Methane Avoidance and Biomass sectors, in general, because these projects do not require that many workers to be developed. The Biomass and Wind Energy sectors are the ones generating the largest number of indirect jobs, as shown in Table 6.

5.3 Economic contribution (contribution to income generation, financial contribution to the local population and use of technology)
Our findings also demonstrate an economic impact of CDMs in Brazil that is greater than the average environmental outcome related to SD. Overall, most of CDMs intend to somehow contribute to a specific economic aspect such as the "Articulation with other sectors", adding up to 163 projects, 74% (weighted average) being Wind and Biomass the main sectors in the criteria.

Almost half of the CDMs analyzed intend to contribute to increase the population's income, as shown in Table 5. While this trend occurs across almost all sectors, those intending

Sector	Number of projects Total	Less than 400 hired employees		More than 400 hired employees	
		# of projects	(%)	# of projects	(%)
Landfill gas	*54*	53	98%	1	2%
Biomass energy	*44*	39	89%	5	11%
Methane avoidance	*36*	36	100%		
Hydro	*33*	24	73%	9	27%
Wind	*25*	18	72%	7	28%
EE industry	*1*			1	100%
EE services	*7*	7	100%		
EE supply side	*1*	1	100%		
Fossil fuel switch	*8*	8	100%		
Fugitive	*1*	1	100%		
N_2O	*4*	3	75%	1	25%
Own generation	*1*	1	100%		
PFCs + SF6	*2*	2	100%		
Reforestation	*2*	1	50%	1	50%
Total	*219*	194	*84%*	25	*11%*

Source(s): based on MCTIC (2020)

to contribute most to this dimension are Biomass, Hydro and Wind. The latter two are large-scale sectors requiring more expensive and specialized labor. They also involve greater articulation with the local population, since the nature of the projects developed within these sectors requires the mobilization of different types of professionals, such as engineers, consultants, and legal services.

Other sectors, like the EE industry, NO_2 and Reforestation, also intend to play a relevant role in improving income generation, although they accumulate a very small proportion of CDM projects. These sectors contribute to income generation either by transferring a share of carbon credits revenue to the local population (like the CDM project employees), or by distributing the value or the electricity itself to the local population free of charge. Once again, as shown in Table 5, projects in these sectors represent only a small share of CDMs.

On the other hand, Landfill and Methane Avoidance are those sectors that least contribute to income generation, as shown in Table 5. This does not imply that these sectors do not play an active role in generating income, but that their specificities are not as favorable to this dimension as the leading sectors mentioned before. Also, it is important to emphasize that the understanding of the meaning of "contributing to income generation" tends to vary from proponent to proponent, and in general the information disclosed is not crystal clear.

Another important finding of this study is that 54% of the CDMs analyzed intend to promote "financial contribution to the local population through courses, environmental and cultural improvements", as shown in Table 5, and virtually all sectors (except for EE services and EE supply side and Fugitive, accumulating only nine projects in total) intend to contribute to some extent to this dimension.

This indicator connects economic issues with social and environmental aspects. These CDMs intend to develop courses, training and other types of knowledge dissemination to local population. They also contemplate social improvements, such as church renovation or schools' creation, specifically responding to local population's demands. As shown in Table 5, Methane Avoidance, Biomass and Hydro projects are those intending to contribute the most in this sphere.

Finally, another important finding of this study regards the use of foreign technology. We can see in Table 5 that only 22% of all CDMs rely on foreign technology. With the exception of Hydro projects, most large-scale activities are those importing technology. In this respect, we found that courses, as well as other kinds of knowledge dissemination practices, happen mostly with local labor, and not through know-how transfer or foreign employees. This mechanism is contrary to the principle of UNFCCC Climate Conferences, which stress the importance of developed countries transferring technology and know-how onto developing countries (UNFCCC, 2011).

This does not imply that technology is not being transferred. On the contrary, the Wind sector is a good example of successful technological transfer, since many technologies that were previously imported started being developed locally, in a cheaper way. This explains why this sector involved the largest number of projects mixing local and foreign technologies. Likewise, many projects in the Landfill and Methane Avoidance (swine farming and landfill treatment, for instance) sectors locally develop new technologies (Doranova, Costa, & Duysters, 2010; Costa-Júnior *et al.*, 2013).

6. Conclusion
CDMs go way further intending to reduce GHG emissions in Brazil. As described in previous sections, they actually intend to promote SD in all three spheres (environmental, social and economic). Beyond GHG emission reduction, 61% of all CDMs seek to promote other environmental impacts. After all, CDMs were conceived with environmental aspects in mind.

However, what was actually surprising about our findings was that 91% of our sample claimed to seek for social improvements in working conditions and job creation. These results are consistent with Olsen and Fenhann (2008), but even more sensible.

These findings not only surpass by far the environmental contribution of these projects, but also contradict previous studies which found mixed results (Kim, 2004) or no evidence of SD in CDM host countries (Sutter & Parreño, 2007).

In terms of CDM social impacts in Brazil, we could see that large-scale projects contribute the most to "income generation and articulation with other sectors", the strongest of all SD dimensions in the country (Seres & Haites, 2008; Costa-Júnior et al., 2013). Said large-scale projects' activities are subjected to high level of regulation, and must comply with strict and well-established environmental standards, positively affecting local communities. Biomass and Methane Avoidance stand out in terms of courses dissemination, energy distribution at reduced cost and schools construction, and other infrastructure activities. These activities for sure can help foster local development and positively contribute to improve local population's income and standard of living. These are ultimate goals in terms of local impacts. Developing nations in general should critically assess and scrutinize the nature of CDM activities beyond GHG decrease, in order to favor those with greater potential to play an active role in increasing employment and income. As shown before, in Brazil, those projects are the ones requiring more skilled labor (Godoy, 2013; Godoy & Saes, 2016).

However, there is a tradeoff in terms of the number of jobs created and their relative impact on improving income. We demonstrated that in Brazil most CDMs were small-scale projects, employing less than 400 workers. While they help creating a bulky number of jobs, these projects require less skilled workers and hence, contribute the least to income generation. Therefore, in terms of policy implications, local programs should balance income generation with number of jobs, to assure that a significant number of people are employed, while a considerable share of them manages to improve their income. This is by no means a trivial endeavor, but one that should be taken on board and encouraged by developing countries.

From an economic perspective, the results are in line with previous work focusing on technological transfer and skilled labor (Michaelowa et al., 2019). There are indications that Brazilian CDMs projects mostly rely on local technology. These results provide further evidence in favor of the local impact of CDMs in Brazil. Depending on the sector, for instance NO_2 and the EE industry, firms might rely almost exclusively in foreign technology. This means that depending on the sector and the nature of the activities they develop, nations might not be able to replicate Brazilian results. One way of overcoming this is to encourage projects in those sectors relying least in foreign technology, such as Fugitive, Methane Avoidance and Wind, despite this not always being a trivial endeavor. Brazil, for instance, has great potential in renewable energy, such as wind, solar and hydro, and public policies should foster emission reduction projects in these sectors.

As far as the number of projects is concerned, we could see that those sectors accumulating the largest number of CDM projects are Biomass (67%), Hydro (50%), Methane Avoidance (50%) and Landfill Gas (46%). Among these, the swine farming projects are the ones that most act in several activities at once, such as organic fertilizer production, development of courses for the local population, odor reduction in the farms, incentive to plant different cultures, among other measures. Conversely, we also found that sectors accumulating a very small number of projects – sometimes a single project - demonstrated more SD impact than their counterparts: this is the case, for instance, of the EE industry and Reforestation sectors. It is also worth mentioning that in some sectors – like Biomass, for instance – more than others there was a prevalence of projects that were already sustainable prior to CDMs.

As for implications, there are indications that CDM is a feasible way to foster SD goals. Since a project development promotes local SD, public policies could take advantage of this mechanism. A CDM is directly linked to Agenda goal 13, affirming "take urgent measures to combat climate change and its impacts". But, through its complementary SD actions beyond emission reduction, such as job creation or other financial support, CDM is also linked to another Agenda goal 2030: the first one, "end poverty in all its forms everywhere". In this sense, GHG emission reduction projects can be great allies of public policies, in terms of encouraging measures to comply with the 2030 Agenda.

Regarding future studies, we suggest that other countries could have their projects analyzed as we have done for Brazil. Also, it is recommended that upcoming work focuses on indicators as taxation, state incentives or sector policies. Qualitative studies could be developed to analyze the effects of projects in terms of SD.

As limitations of our study, we highlight that our analysis is focused on *ex ante* CDM and SD proposals, and not on ex-post measures. This means that we could not assess the extent to which and how CDM proponents actually implemented every action declared in Annex III. Even though assessing this angle and gathering data about it is challenging, relying solely on our *ex ante* sample already made it possible to conclude that there is great potential for measures to be adopted aiming at SD in CDM host countries – not only in Brazil, but in countries like India and China.

We stress, however, that there are currently no regulations, mandatory targets or strict rules related to SD in Brazil related to CDM. There are no monitoring devices to both check and enforce the proposed actions. It is the key to bear in mind that if stricter standards with mandatory patterns and different norms are implemented, new transaction costs might emerge. Consequently, expenses may be higher due to monitoring, gathering new information in order to implement new activities and other kinds of costs arising from stricter rules.

Thus, it is necessary to take into consideration that GHG emission reduction programs linked to stricter SD norms could increase cost. There lies a paradox resulting from the need to expand measures related to SD in developing countries, without, however, bringing further obstacles to the implementation of new GHG emission reduction projects.

Note

1. The year 2006 had a huge number of biomass projects, and in order to further diversify the sectors analyzed, a smaller number of projects was selected to be analyzed in that year compared to others.

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Corresponding author
Paula Sarita Bigio Schnaider can be contacted at: paula.schnaider@usp.br

Associate Editor: Adriana Marotti de Mello