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Coping with climate change: fair burden sharing among industrialized and developing countries

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Author’s declaration

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Graz, October 2018 Yadira Isbi Mori Clement

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Abstract

The Paris Agreement requests that both developed and developing countries contribute to mitigation of climate change, but developing countries still require support as their mitigation capacity is limited by social, technological and financial constraints. Prior to the Accord, this support was given through the Clean Development Mechanism (CDM); however, in order to achieve the 2°C target, new climate mechanisms are required, which go beyond mere offsetting and achieve net emission reductions in broad sectors in developing economies, while simultaneously promoting sustainable development. This dissertation analyzes the impacts of CDM in Brazil, the country case study of this research, and then investigates the effects of trade arrangements with climate-related provisions as alternative for a new market mechanism in the post-Kyoto era. For the design of a new market mechanism, impact assessments of the mechanisms already in force are essential. Regarding the impacts of the CDM, two econometric approaches are applied to analyze to which extent CDM has led to sustainable development benefits. All CDM project types improved local income but only hydro power projects contributed to reduce poverty and inequality for the period analyzed. To complement the previous assessment, cross-sectoral effects in employment over time are investigated. CDM had small and transitory effects on sectoral employment at the local level regardless of project type. Finally, a Computable General Equilibrium model was applied to explore the effectiveness of a preferential trade agreement between Brazil and the EU as a candidate for a new climate mechanism. It is found that trade agreements promoting climate-related foreign direct investment are an effective alternative in reducing CO_2 emissions, while positively impacting the Brazilian economic performance. Overall, a combination of climate instruments could therefore work as effective package to avoid conflicts between objectives.

Zusammenfassung

Das Pariser Klimaabkommen fordert, dass Industrie- und Entwicklungsländer zu Klimaschutz beitragen. Entwicklungsländer benötigen dabei jedoch Unterstützung auf Grund von sozialen, technologischen und finanziellen Barrieren. Vor dem Pariser Abkommen leistete der Clean Development Mechanism (CDM) diese Unterstützung. Um das 2°C-Ziel zu erreichen, sind jedoch neue Mechanismen erforderlich, die über eine bloße Kompensation hinausgehen und Nettoemissionsreduktionen in vielen Sektoren erzielen und gleichzeitig eine nachhaltige Entwicklung fördern. Diese Dissertation analysiert zunächst die Auswirkungen von CDM in Brasilien als Länderfallstudie und untersucht dann die Auswirkungen von Handelsabkommen mit Klimaschutzvorkehrungen als Alternative zu einem neuen Marktmechanismus in der Post-Kyoto-Ära. Für die Gestaltung eines solchen Mechanismus sind Folgenabschätzungen bereits gesetzter Maßnahmen unerlässlich. Mittels ökonometrischer Ansätze werden daher die Auswirkungen des CDM auf nachhaltigen Entwicklung analysiert. Alle CDM-Projekttypen erhöhen das lokale Einkommen, aber nur Wasserkraftprojekte tragen zur Reduktion von Armut und Ungleichheit bei. Ergänzend werden Sektor übergreifende Effekte auf die Beschäftigungsentwicklung untersucht. CDM führt unabhängig von der Art des Projekts zu geringen und vorübergehenden Auswirkungen auf die Beschäftigung in unterschiedlichen Sektoren auf lokaler Ebene. Schließlich wird ein Computable General Equilibrium-Modell angewandt, um die Wirksamkeit eines Handelsabkommens mit Klimaschutzvorkehrungen zwischen Brasilien und der EU als Kandidat für einen neuen Klimamechanismus zu untersuchen. Handelsabkommen, die klimabezogene ausländische Direktinvestitionen fördern, erweisen sich als eine wirksame Alternative zur Verringerung der Emissionen und wirken sich zudem positiv auf die brasilianische Wirtschaftsleistung aus. Insgesamt könnte eine Kombination von Klimainstrumenten somit als wirksames Paket dienen, um Zielkonflikte zu vermeiden.

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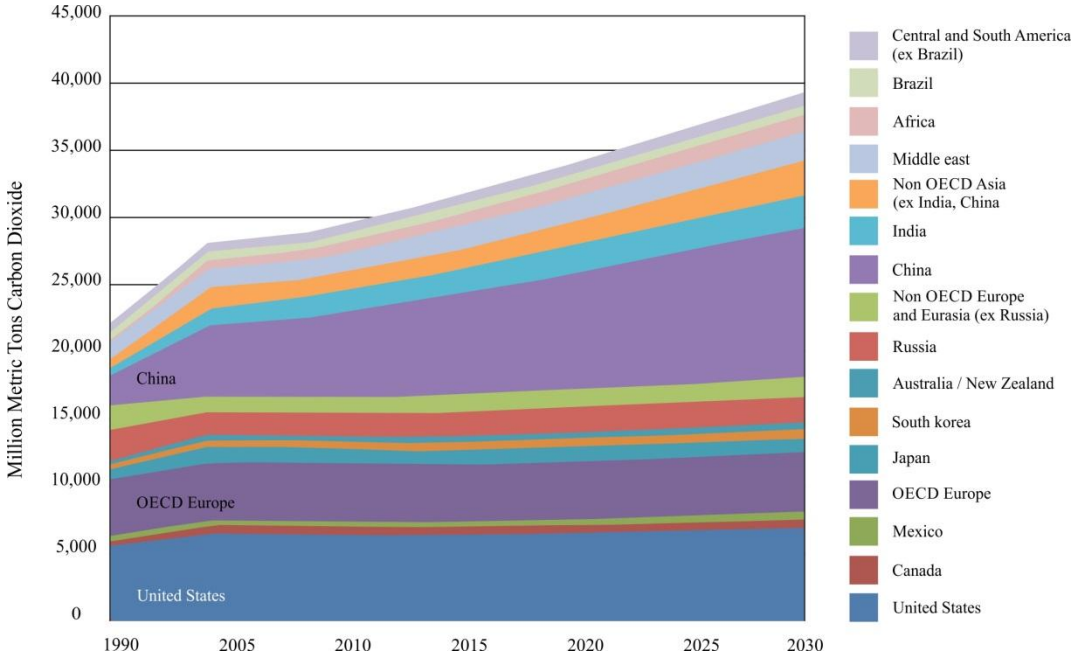
1. Introduction

1.1. Problem statement and motivation

According to the Paris Agreement[1] (2015) not only developed but also developing countries are now officially involved in pursuing climate goals[2]. The successful integration of emerging and developing countries into global climate negotiations through voluntary Nationally Determined Contributions (NDCs) represents a critical step forward in this long pathway to achieve global decarbonisation. During the last decades, the contribution in CO_2 has been increasing in the developing world (Figure 1); in particular, China, India, Brazil and other non-OECD countries have significantly augmented their emissions. This fact highlights the importance of active integration of all countries in climate negotiations.

Figure 1: Global CO_2 emissions by main regions for period 1990-2030 (MMT CO_2)



Source: Global Carbon Project (2011).

However, the implementation of the current NDCs may not be sufficient to achieve the 2°C target (Rogelj et al. 2016; Schleussner et al. 2016; Boyd et al. 2015). Estimations show that although these voluntary contributions may lower GHG emissions, these reductions may lead to achieving a median warming of 2.6-3.1°C by 2100 (Rogelj et al. 2016). Thus, additional measures and actions have to be taken in order to keep global warming below the 2°C target.

[1] Under this Accord, each participant country has to determine and plan their GHG mitigation targets (also known as Nationally Determined Contributions), which have to be updated and increased every five years. These contributions are voluntary and according to country's possibilities but they should also be ambitious to achieve global climate goals such as the 2° C target.

[2] Prior to the Paris Agreement, the Kyoto Protocol (1997) used to rule global climate governance. Under Kyoto, there exist two main country groups: Annex I and non-Annex countries. Only Annex I countries (industrialized/developed economies) were responsible in achieving GHG emission reductions, so they had binding targets while non-Annex countries (developing economies) were exempt from this obligation. With the Paris Agreement, this classification is not longer in force as all parties (developed and developing countries) must set mitigation targets voluntarily.

Although both developed and developing countries are now officially involved in pursuing climate goals, the latter are still the most vulnerable in this context as their mitigation capacity is limited by social, technological and financial constraints (UNFCCC 2007); therefore, they nevertheless require support to accomplish this global goal. Before the Accord, this support has been taking place through one of the flexibility instruments introduced by the Kyoto Protocol (1997): the Clean Development Mechanisms (CDM), an instrument with a twofold objective (CDM-Article 12): "*to help developed countries fulfil their commitments to reduce CO_2 emissions and to aid developing countries in achieving sustainable development*". Several definitions for *sustainable development* have been discussed in the literature, but this concept can be generally understood as the intersection of three dimensions or pillars (WCED 1987): social equality, economic growth and environmental protection. Under the CDM, the sustainable development criteria should be based on country-specific development priorities with a focus on these three dimensions (Olhoff et al. 2012).

Despite of the achievements attained by the CDM, this instrument has also been subject to several criticisms due to several pitfalls identified along the more than 10-years of implementation (Shishlov and Bellassen 2012). Concerns regarding the effective achievement of the sustainable development objective have been discussed even before the official launch and implementation of the CDM (Banuri and Gupta 2000; Kolshus et al. 2001). Potential conflicts and trade-offs between the two CDM objectives may arise when trying to fulfill both targets: as the CO_2 emission reductions is the only objective that is rewarded by the market through the generation of Certified Emission Reduction (CER) credits, the CDM may not create by itself adequate incentives to fulfill the sustainable development objective (Ellis et al. 2007; Paulsson 2009).

Moreover, the missing obligation for the host countries to verify project's achievements in this aspect, in contrast to the existing strict monitoring of CO_2 emission reductions, might exacerbate the trade-off (Olsen and Fenhann 2008). Since the CDM is a market instrument that targets least-cost mitigation projects rather than poorest communities, the sustainable development objective was expected to be overtaken by the reduction emission goal. In addition to this concern, other criticisms have pointed out the lack of additionality and the high transaction costs behind the CDM (Michaelowa 2012).

Regarding the lack of additionality, this refers to the potential of a CDM project to contribute to real and additional emission reductions. Although rules have been established to ensure a project's additionality, the calculation of emission reductions may face difficulties as it requires setting a baseline which is based in many cases on hypothetical scenarios. Although third parties take part in verification of emission reductions, measurements are not exempt from difficulties (Monceau and Brohé 2011). With respect to the transaction costs, it is argued that CDM projects may incur additional bottlenecks at several points e.g., during a project's registration and during the issuance of carbon credits (CER) due to administrative procedures. These bottlenecks translated into delays and additional costs may undermine a project's viability (Chadwick 2006).

From the need of improving these shortcomings of the CDM as well as scaling-up actions the demand for new climate mechanisms emerges to achieve more stringent climate goals in developing economies. Since the Conference of the Parties (COP) in Durban (2011), the future design of a new market-based mechanism (NMM) has been discussed, which go beyond mere offsetting and can achieve net emission reductions through scaling up mitigation actions in broad segments[3] (UNFCCC

[3] What broad segments means, has to be defined by Parties and it may encompass sectoral and/or project-specific basis (UNFCCC 2013).

2012). Until now, there is still discussion on how this mechanism would work and how this would be implemented. Although Article 6 of the Paris Agreement establishes and encourages voluntary cooperation among parties to achieve their NDCs through a *mechanism* (Article 4.4), no other specifications regarding its characteristics and nature are mentioned in the Accord[4].

As the CDM represented the primary mechanism to support mitigation efforts in developing countries under the Kyoto Protocol, this experience can provide policy-makers with lessons for future improvements as well future design of new climate mechanisms in the context of the Paris Agreement. For this reason, ex-post assessments are essential to verify the achievement of the CDM twofold objective as well as to understand how this mechanism delivered (or did not deliver) the expected goals. In the empirical literature of the impacts of CDM on sustainable development, most studies are ex-ante analyses based on information provided by the Project Design Document (PDD) of the CDM project (Lema and Lema 2013; He et al. 2014), which is basically data on project's expected or potential impacts at the local level, and thus it does not reflect what effectively occurred after a project's implementation. There are still very few studies available that attempted to conduct ex-post assessments using empirical data (Mori-Clement 2018).

Regarding the NMM, diverse options have been proposed, from project-based to sectoral approaches. Although some of them have been discussed in depth, there are still few quantitative studies available in this regard. Examples of these proposals are the enhanced version of the CDM or the CDM plus (Brazil 2014), the NAMA crediting[5] or sectoral market mechanisms[6] (Baron et al. 2009; Schneider et al. 2014). Some of these proposals (e.g., the sectoral crediting mechanism) have been broadly discussed including implementation alternatives, political feasibility and other challenges ahead; while others offer a general background without further specification as it is the case of some country proposals such as the CDM plus (Brazil 2014).

As an alternative to the NMM, other scholars have proposed preferential trade agreements (PTAs) with climate-related provisions (Dong and Whalley 2010; Leal-Arcas 2015; Brandi 2017; Morin and Jinnah 2018). These bilateral arrangements may enhance not only accessibility but also dissemination of goods that could contribute to achieving mitigation objectives through the removal of import and non-tariff barriers (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017). Trade liberalization of environmental goods[7] has the potential to decrease pollution-abatement costs and to generate incentives to adopt cleaner technologies in the importing country, while boosting markets of these goods in the exporting country (Brandi 2017). Despite of the high potential of trade agreements to deal with mitigation, empirical analyses are still very limited.

In the context of the Paris Agreement, trade elements have been incorporated in the NDCs to deal with climate contributions. Nearly 45% of the NDCs included them directly without further

[4] This mechanism, which also shares the twofold objective of the old CDM, is also informally called in the literature as the Sustainable Development Mechanism (SDM) (Marcu 2016).

[5] The Nationally Appropriate Mitigation Actions crediting or NAMA crediting is a mechanism based on NAMAs that aims at reducing emissions below an agreed crediting baseline, thus generating carbon credits.

[6] The sectoral crediting mechanism (SCM) is one sectoral approach that has been extensively discussed in the literature. It is a mechanism that aims at issuing carbon credits in a host country (developing or emerging economy) only if emission reductions are achieved below a crediting baseline, which is set for the entire sector (Bosi and Ellis 2005). This mechanism is not binding, so if reductions are not achieved, then no penalties will be imposed (Schneider and Cames 2009).

[7] Although there is no a common-agreed definition of "environmental goods" (and services) due to complexities in defining this sector (Vossenaar 2016), it could encompass those goods (and services) used "*to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related waste, noise and eco-systems*" (UNSTATS/OECD 1999, p.9). Therefore, it may include all those goods (and services) related to clean-technologies, energy efficiency, pollution control, among others (Bucher et al. 2014). In addition to that, it might include low carbon products for final consumption as well as inputs to produce (and consume) low-carbon products (Dong and Whalley 2010).

specifications or in a very general way, while 22% included trade-specific measures (Brandi 2017). These trade-related references aim at targeting the renewable energy sector (100%) with a focus on technology transfer (63%). Regarding specific trade measures, there are few and some examples are trade regulations on climate grounds (11%) and the removal of trade barriers in environmental goods and technologies (6%). The latter has been mainly proposed by small countries[8]. Some concrete proposals of trade barrier removal are the reduction of import duties on renewable energy equipment[9] and tariff reductions in specific vehicles (e.g electric cars)[10]. In the case of top emitters such as the EU, although its NDCs does not explicitly refer to trade-related measures, the EU has been actively involved in incorporating climate-related provisions in its preferential trade agreements with emerging and developing economies[11] in the last decades (Morin and Jinnah 2018).

This dissertation aims at addressing the research gaps discussed above through three papers, which complement each other, while taking as country case study Brazil, the emerging country with the third largest CDM investments worldwide (UNEP 2015). The first two papers focus on conducting ex-post assessments on the impacts of CDM on sustainable development, while the third paper presents a quantitative analysis in which the implications of adopting a preferential trade agreement with a climate-focus are analysed. In the next subsection, the country profile of Brazil is presented and then the main research objective of this dissertation is drawn.

1.2. Brazil: a country profile

Brazil is the third largest country worldwide in terms of the number of CDM projects and also pioneering in CDM investments. From its first registered project[12] in 2004 until 2016, around 338 projects have been registered and more than 50% target the energy sector (UNEP 2016). One decade hosting CDM projects makes Brazil an interesting case study to assess impacts of CDM investments over time. In addition, the heterogeneous distribution of projects within the country may contribute to evaluate impacts of CDM investments at the municipality level.

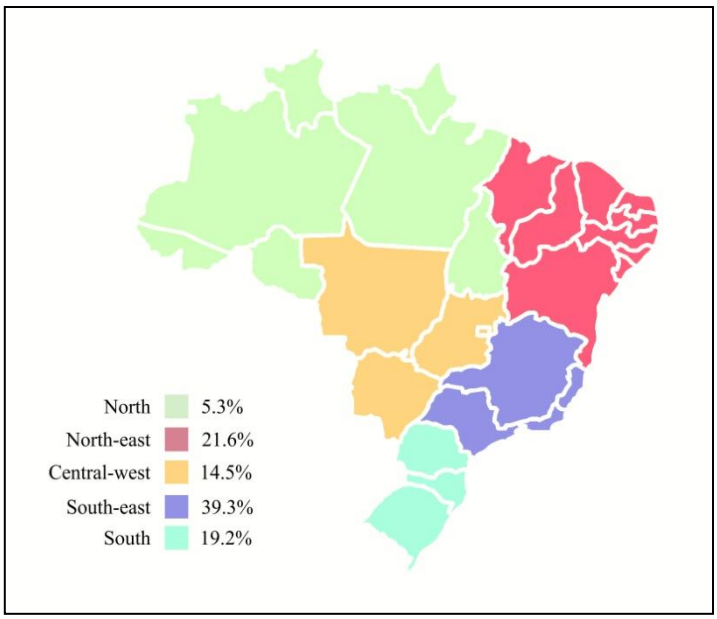
CDM projects in Brazil can be divided into two main categories: renewable energy projects (61%) and waste handling and disposal projects (34%). The remaining (5%) are projects in the chemical and manufacturing industries. Within the renewable energy sector, hydro (45%), wind (27%) and biomass energy (22%) are the main project types. Most predominant subtypes in this sector are run-of-river hydroelectric power (hydro projects), wind (wind projects) and bagasse power (biomass energy projects). In the waste handling and disposal sector, main project types are methane avoidance (56%) and landfill gas (44%). Regarding subtypes, most important categories are landfill flaring, landfill power (landfill gas projects), and manure (methane avoidance). With regard to project scale, almost 70% of the projects are large scale[13], while the remaining 30% are small. In the renewable energy

[8] By the moment, the removal of trade barriers in environmental goods and technologies in their NDCs has been included by Bahamas, Cuba, Djibouti, Guyana, Lao PDR, Niue, Saint Lucia, Saint Vincent and the Grenadines, Seychelles and Togo.
[9] This specific trade measure has been proposed by Guyana and Lao.
[10] This specific trade measure has been proposed by Bahamas, Saint Lucia, and Saint Vincent and the Grenadines.
[11] Some examples of climate-related provisions adopted are the removal of trade and non-trade barriers on climate good and services relevant to mitigation (EU-Colombia and Peru 2012; EU-Korea 2010; EU-Georgia 2014), cooperation in the renewable energy sector (EU-Mexico 1997; EU-CARIFORUM 2008; EU-Central America 2012; EU-Georgia 2014; EU-Singapore 2014); promotion of FDI in environmental technologies and services (EU-Korea 2010; EU-Central America 2012) or strengthening carbon market mechanisms (EU-Central America 2012)[11].
[12] The first CDM project registered worldwide was a landfill gas project in the municipality of Nova Iguacú in Rio de Janeiro federate state in 2004.
[13] Large and small scale projects follow different rules, but in general, requirements are less strict in the last case. To fall under the category of small project, for instance, a project in renewable energy must be 15MW or less of output per year; in

sector, in a similar way, 70 % are large; in particular, 100% of the wind projects are of large scale. In the waste handling and disposal sector, 61% are large projects; where all landfill gas type projects are large, while the methane avoidance at almost 80% (UNEP 2016).

Regarding the geographical distribution of the CDM within the country (Figure 2), the South-east concentrates 39.3% of the total; the North-east 21.6%, the South 19.2% and the Central-west 14.5%. Few projects (5.3%) were implemented in the North (Amazonian), a region characterized by high forest density. Regarding renewable energy projects, more than 50% are located in the South-east and South region (30.4% and 22%, respectively), and 28% in the North-east. Regarding waste management and disposal projects, 51% of total are located in the South-east, 18% in Central-west and 17% in the South (UNEP 2016).

Figure 2: Geographic distribution of CDM projects by macro-region in Brazil



Source: Own illustration, based on UNEP (2016).

With respect to the CDM sustainable development criteria, the Brazilian Designated National Authorities (DNA) have explicit criteria to determine the contribution of CDM projects to sustainable development. These criteria considers six areas: 1) contributions to local environmental sustainability, 2) the improvement of working conditions, 3) net employment creation, 4) fair income distribution, 5) technology development, and regional integration and linkages with other sectors (ICGCC 2003). Although Brazil had one of the most stringent DNA processes (Hultman et al. 2012), the DNA has not established any indicator or measurement tools for monitoring and evaluating the contribution of CDM projects in the territory to local sustainable development (Americano 2008).

Regarding its NDCs, Brazil intends to reduce GHG emissions by 37% below 2005 levels in 2025 and by 43% in 2030 (Brazil 2016). The renewable energy sector is priority for mitigation and there is a domestic target of increasing the share of renewables in the energy mix to 45% by 2030, which

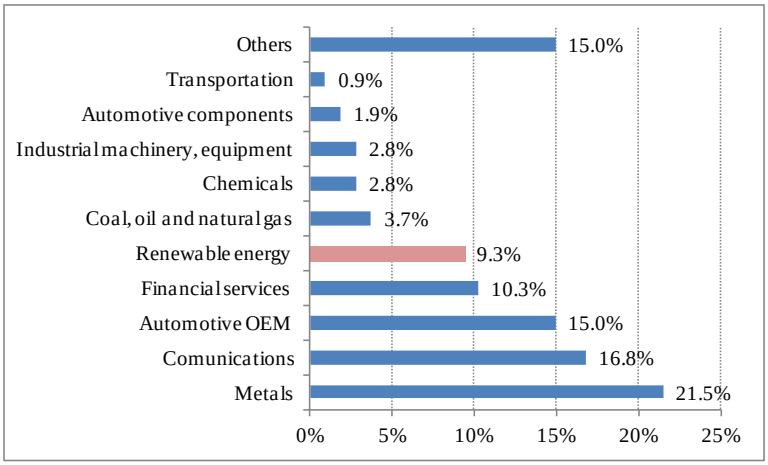
the case of energy efficiency projects, these must reduce energy consumption by 60 Gigawatt hours per year or less. For other categories, these must reduce up to 60,000 tons of CO_2 annually (Carbon Market Watch 2000).

includes expanding the use of renewable sources (other than hydro, i.e., wind, solar, biomass, biogas) in the total energy share between 28% and 33% by 2030, and increasing the share of renewable (other than hydro) in the power supply to at least 23% by 2030.

The Brazilian electricity sector is the largest in South America. Renewable energy sources account for almost 80% of total electricity generation and hydropower represents 65%, while biomass 9.4%, wind 6.7% and solar 0.02% (EPE 2017b). As the energy mix strongly relies on hydropower, this makes Brazil vulnerable to power supply shortages in drought years as it was the case in 2001, 2012 and 2015 (Krishnaswamy and Stuggins 2007; Schmidt et al. 2016). Therefore, energy mix diversification should be then considered as backbone strategy to enhance energy security and decrease reliance on fossil fuels (Silva et al. 2016). Although the share of other renewable energy sources such as wind and solar are still low in the energy mix (6.7% and 0.02%, respectively), their potential is very large[14] (CRESESB 2001; Bueno et al. 2006); this makes Brazil an attractive market for investments in renewable energy technologies.

Figure 3: Share of sectoral greenfield investment by the EU in Brazil

(Period 2006-2015, EUR million)



Source: APEX-BRASIL 2017 (FDI Markets 2016).

Regarding incentives for investments in the renewable energy sector, the Program of Incentives for Alternative Electricity Sources (PROINFA) launched in 2002 has played a role in promoting wind, biomass and small hydropower plants in Brazil[15]. Although solar was excluded from PROINFA, the government considered solar energy as beneficiary of short-term fiscal incentives in the form of tax exemptions and import tax reductions[16]. However, promotion of solar energy is still weak as there are still obstacles to promote technologies other than hydro such as high transmission and integration

[14] The Brazilian North-East is the region with the strongest wind potential during the dry or winter season, which coincides with the season of lower rainfall intensity in the year (CRESBS 2001). Moreover, solar potential is greater in summer, period of the year when energy demand increases (Jong et al. 2013). These seasonal complementarities offer a great opportunity to diversify energy sources as well as represent a challenge how to integrate renewable and intermittent energy sources into the electricity sector (Oliveira et al. 2017).

[15] Nearly 95% of projects have been financed by this program by 2011 (Pereira et al. 2012).

[16] Under the Special Taxation Regime of Incentives for the Development and Production of Alternative Energy Source (REINFA), solar is exempt from the state value-added tax (ICMS) and social integration/social security contribution taxes (PIS/COFINS) on net electricity as well as import tariff reductions from 14% to 2% on capital goods and related components.

costs (Ferreira et al. 2018; Schmidt and Guedes-Ribeiro 2018). With respect to fossil fuels, oil and natural gas are subject to several taxes at the federal, state and municipal level[17] (OECD 2014) as well as tax exemptions under several incentive regimes[18] to promote their investments (OECD 2014; Nuamy-Barker 2015).

In terms of trade, the EU is Brazil's second largest trading partner accounting for almost 20% of its total trade in 2016[19](EuroStat 2017). Its trade with the EU accounts for 30.8% of the EU's total trade with Latin America. This relevance is not only reflected in trade but also in FDI considering that for the EU, Brazil is the third largest FDI inflow destination worldwide (APEX-BRASIL 2017). At the sectoral level (Figure 3), the estimated announced productive FDI[20] in renewable energy by the EU in Brazil represents 9.3% of the total for the period 2006-2015 (FDI Markets 2016).

1.3. Research objectives

The overall objective of this dissertation is to investigate the economic impacts of climate mechanisms in developing countries. For the design of new climate mechanisms under the Paris Agreement, assessments of the mechanisms already in force are essential. With this in mind, I depart from the CDM experience and then explore the effectiveness of a trade agreement as a potential candidate for a new climate mechanism. From this overall objective, three specific objectives are framed; each of them representing one research paper, respectively and taking Brazil as a country case study:

1. To test empirically for the impacts of CDM investments on sustainable development across Brazilian municipalities, with a focus on income and poverty indicators;
2. To complement the previous research objective with an assessment of cross-sectoral effects in local employment over time across Brazilian municipalities with CDM projects;
3. To assess the impacts of a preferential trade agreement with climate-related provisions between Brazil and the European Union on emission reductions and economic performance in Brazil;

From these research objectives, the following research questions are formulated:

1. Did the CDM deliver sustainable development benefits across Brazilian municipalities for the period analyzed?
2. Did CDM projects contribute to stimulating cross-sectoral employment in Brazilian municipalities?

[17] Some examples are the CIDE fuel consumption tax (for imports and retail sales) and social security contributions such as the PIS (Program of Social Integration) and the COFINS (Social security financing contribution).
[18] Some examples are the Special Incentive Regime for Infrastructure Development (REIDI) which exempt companies from paying social security contributions such as the PIS and the COFINS on goods for infrastructure projects, the Special Tax Regime for Goods used in the Exploration (REPETRO) which exempt companies from the PIS, the COFINS and the IPI (Excise duty on industrialized products) when importing goods by sea for research activities and extraction or the (REPORTO) which exempt companies from the PIS; the COFINS and the IPI when investing in port infrastructure. Oil producers are exempted from the payment of corporate income taxation: the corporate income tax (IRPJ) and the social contribution tax on profits (CSLL) according to the new tax regime law established in 2017 (INESC 2018).
[19] EU imports from Brazil are dominated by primary products, (i.e., foodstuffs, beverages and tobacco products (18.2%), vegetable (17.9%) and mineral products (16.3%)), while EU exports are mainly on machinery and appliances (26.6%), chemical products (23.6%) and transport equipment (13.6%).
[20] According to FDI Markets, this data on announced productive FDI represents all greenfield investment projects or new productive investments made by existing companies

3. Are preferential trade agreements effective in achieving mitigation goals without compromising economic performance?
4. Can trade arrangements be considered as a potential candidate for a new climate mechanisms in the context of the Paris Agreement?

2. Theoretical framework and empirical literature review

This section introduces the theoretical framework to analyze the research objectives of this dissertation as well as reviews the empirical literature. It is structured in three sub-sections, each corresponding to one paper. In subsection 2.1, the framework applied to analyze the impacts of CDM on sustainable development is discussed, while in subsection 2.2 the cross-sectoral employment effects of CDM projects are reviewed. Finally, the theoretical framework on the impacts of preferential trade agreements on emission reductions is presented in subsection 2.3.

2.1. The impacts of CDM on local sustainable development (paper 1)

Research that discussed the theoretical ability of CDM projects in generating synergies between environment and local livelihood improvements have identified a high potential in renewable energy projects (Troni et al. 2002). This research used a framework that links the provision of clean energy to local sustainable development to explain causal effects. Under this framework, the access to energy is a key vehicle that drives sustainable development through the provision of basic needs (e.g., cooked food, piped water), realization of productive activities (e.g., manufacturing, commerce) and protection of local environment; thus generating improvements in livelihood conditions (UNDP 2000, 2005).

In the context of CDM, the effects of small-scale rural renewable energy projects in local sustainable development have been translated into the opportunities generated by improved access to clean energy services by poor households through income diversification due to enterprise development and employment generation, improved health due to access to cleaner water as well as reduced fuel wood consumption, education due to lightning appliances as well as time available for studying at night, gender benefits due to less time collecting firewood and water by women, among other benefits (Troni et al. 2002, Brunt and Knechtel 2005). In a similar way, effects in sustainable development have been analyzed in other sectors such as forestry (Smith and Scherr 2002). Therefore, distinguishing impacts by project type is relevant to understand the nature and causality of effects at the local level.

Research on the impacts of CDM on sustainable development has attempted to assess effects using several group indicators that encompass the most relevant areas of any sustainable development strategy: the economic, the social and the environmental. Some common indicators used to evaluate the economic aspects of sustainable development achievements of CDM projects are households' and/or per capita income (Subbarao and Lloyd 2011; Bayer et al. 2013) as well as generation of local employment (Sutter and Parreño 2007; Alexeew et al. 2010; Subbarao and Lloyd 2011; Wang et al. 2013) and technology transfer (Schneider et al. 2008; Dechezlepretre et al. 2009; Costa-Junior et al. 2013; Lema and Lema 2013).

With respect to the social aspect of sustainable development, some studies have focused on analyzing impacts of CDM projects on health, education (Subbarao and Lloyd 2011) and poverty alleviation (Sirohi 2007; Crowe 2013). Some indicators used to analyze health issues are for instance improved access to safe potable water and reduced exposure to indoor air pollution, while for assessing impacts on education indicators used are the number of children attending school and the time spent studying (Subbarao and Lloyd 2011). Regarding poverty alleviation, studies available on this topic are still very limited (Dirix et al. 2016). Indicators used in analyzing pro-poor benefits are rural income and affordability of clean energy (Sirohi 2007; Crowe 2013). Although poverty

alleviation is not explicitly part of the CDM mission, this aspect is integral of any sustainable development strategy; therefore, CDM projects should deliver a minimum of pro-poor co-benefits (Sirohi 2007; Dirix et al. 2016).

Finally, in the environmental sphere, research focuses on the impacts on environmental amenities such as air, water or soil and forest (Sutter and Parreño 2007; Alexeew et al. 2010; Subbarao and Lloyd 2011; Crowe 2013). Some examples of the proxies used to evaluate environmental impacts of the CDM are water quality (Aleseew et al. 2010; Subbarao and Lloyd 2011; Crowe 2013), air quality (Sutter and Parreño 2007; Aleseew et al. 2010; Subbarao and Lloyd 2011), soil quality (Alexeew et al. 2010) and increased forest area (Subbarao and Lloyd 2011). Additionally, other studies have applied scores based on a list of indicators or compound indexes that represent the multidimensionality of the sustainable development concept (Nussbaumer 2009; Alexeew et al. 2010; Drupp et al. 2011; He et al. 2014).

With respect to the main findings from empirical studies, these are not conclusive. Some research have reported positive contributions in terms of increasing local income (Bayer et al. 2013), employment generation (Olsen and Fenhann 2008; UNFCCC 2011; Wang et al. 2013), improved air quality (Olsen and Fenhann 2008) and successful technological transfer (Schneider et al. 2008; Seres et al. 2010). On the other hand, there is a strand of the empirical literature that found no impacts associated with the implementation of CDM projects (Sutter and Parreño 2007; Alexeew et al. 2010; Drupp 2011; Subbarao and Lloyd 2011; Costa-Junior et al. 2013; Lema and Lema 2013). In the particular case of poverty alleviation, CDM projects were found to have very limited or no impact in reducing local poverty (Sirohi 2007; Crowe 2013).

One explanation for the absence of impacts in several empirical studies is that there is an inherent conflicting relationship between the two CDM objectives (Olsen 2007). This hypothesis of the trade-off between the CDM objectives has been empirically tested by few studies that also have analyzed impacts of CDM on sustainable development; all of them have identified a trade-off in favor of the cost-efficient emission reduction target (Schneider 2007; Sutter and Parreño 2007; Alexeew et al. 2010). A second explanation states that there is a "race to bottom" in which host countries have lowered their sustainable development requirements to attract more CDM project developers (Drupp 2011; Alexew et al. 2010).

Regarding the methodologies applied to assess CDM impacts on sustainable development, most studies have adopted qualitative rather than quantitative approaches (Wang et al. 2013) and have relied on information provided by the Project Design Document (PDD) of each CDM project (Lema and Lema 2013; He et al. 2014). The guideline for the design of PDD files requires a section that describes the potential impacts of the project on sustainable development. In general, this description of the sustainable development benefits tends to be vague without clarifying causality effects at the local level as a result of project's activities. Another important drawback of using data from the PDD is that it only reflects potential or expected results and thus, it does not capture real impacts that took place after implementing the CDM project (Nussbaumer 2009).

Some examples of methodological approaches applied in qualitative studies are checklists (Olsen and Fenhann 2008), scoring pattern methods (Subbarao and Lloyd 2011), content analysis (Costa-Junior et al. 2013) or the Multi Criteria Assessment (MCA) and its further adaptations (Sutter 2003). These studies have relied, in almost all cases, on information provided by the PDD of each CDM project (Lema and Lema 2013; He et al. 2014). Regarding quantitative research, very few studies have attempted to analyze the CDM impacts using empirical data. For instance, Input-Output models have

been used to estimate employment flow across sectors at the sub-national level in China (Wang et al. 2013) and a few panel models have tried to estimate the determinants of CDM project's distribution within-country (Bayer et al. 2013) or to assess the fulfillment of the sustainable development goal through cross-country comparisons (He et al. 2014)[21].

In the particular case of Brazil, no quantitative assessment has been conducted yet, but qualitative approaches using data from the PDD as well as stakeholders' interviews have been applied to determine impacts. For instance, Fernandez et al. (2014) analyzed the impacts on local employment, health, education and empowerment of vulnerable people; while Junior-Costa et al. (2013) focused on successful transfer and promotion of cleaner technologies using data from the PDDs as well as case studies. According to these studies, CDM projects have succeed in delivering economic results in the short-term (i.e., employment during construction and maintenance phase, increasing local income), but failed to promote long-term benefits in some Brazilian states.

2.2. Cross-sectoral employment effects of CDM projects (paper 2)

Employment generation is recognized as one of the most crucial approaches to attain sustainable development; that is why, its key role has been featured by the eighth Sustainable Development Goal, which aims at "*promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*" (UN 2015). Job creation is one of the benefits most commonly claimed by different types of CDM projects (UNFCCC 2012; Spalding-Fecher et al. 2012) since these investments are expected to bring a significant stimulus to the local economy along project's life (Olhoff et al. 2004).

Although the PDDs do not delineate the causal mechanisms how different types of CDM projects lead to employment generation, there is extensive literature on employment effects in the context of renewable energy projects. Despite of employment generation being claimed as one of the benefits of promoting renewable energy, it is not straightforward how the causality works. Behind the overall or net employment impact of implementing a renewable energy project, there are three main effects to be taken into account (IRENA 2013). The direct effect describes the direct impact on employment of a project (e.g., construction of a plant); the indirect effect refers to employment generation that takes places in other sectors (e.g., jobs generated in the manufacturing sector – turbines for wind farms), while the induced effect refers to those jobs created due to spending that comes from household's earnings from working in the project. Since the overall impact depends on the direction and size of each effect, it is not possible to determine the net impact on employment a priori.

For all CDM projects, the most visible and direct effects on employment are generated during the construction phase (Altener 2003; May and Nilsen 2015) and also during operation and maintenance activities which requires fewer but highly skilled workers (Ecotec 2003; del Rio and Burguillo 2008; Brown et al. 2012). CDM projects may also generate indirect effects in the context of cross-sectoral employment benefits in sectors such as agriculture, industry, services or construction as well as induced employment through the creation of indirect demand of goods and services (Hillebrand et al. 2006; del Rio and Burguillo 2008; Brown et al. 2012).

[21] Bayer et al. (2013) identified three main determinants of CDM investments across provinces in China for period 2004-2009: high electricity consumption, low per capita income and absence of FDI inflows. He et al. (2014) used the Sustainability-adjusted Human Development Index (SHDI) to determine contributions of CDM across 58 host CDM countries for period 2005-2010.

However, projects might also have the potential to generate contractive effects that could affect energy-intensive sectors such as manufacturing (Hillebrand et al. 2006). The contractive effect describes how the expansion of renewable energy could increase electricity prices and might affect manufacturing production costs, leading to a fall in production as well as a decrease in sectoral employment (Aldy et al. 2011). The net total result on local employment will depend on how much the contractive effect offsets the positive impact at the local level (Wang et al. 2013). A second issue is that although renewable energy projects generate demand for manufacturing goods and services, it is likely that these goods have to be imported from other regions because specific manufacturing components are not produced everywhere; so this might benefit other localities outside the project's site (Adas 2003; del Rio and Burguillo 2008; Brown et al. 2012).

A third issue is related to the durability of the employment effects during a project's life (Brown et al. 2012). Not all renewable energy technologies might be able to generate sustained employment effects at the local level (Komor and Bazilian 2005). That might be the case for wind projects, which may greatly stimulate job creation mainly during construction phase, but not significantly during operation and maintenance stage (Simas and Pacca 2014); in contrast, biomass projects tend to generate more stable job positions because of the extent of its production chain (del Rio and Burguillo 2008).

Regarding empirical studies, ex-ante analyses are the most predominant type of assessments and they apply qualitative approaches that use data provided by the CDM project developer (PDD), which is data based on potential or expected project results. In contrast, ex-post empirical studies on local employment are much scarcer. Du and Takeuchi (2018) estimate the impacts of CDM in rural communities in China by combining a difference-in-differences model with propensity score matching techniques. Findings show that while CDM biomass projects have stimulated local job creation also for unskilled laborers, large-scale CDM hydro and solar projects have contributed to employment generation in primary industry at the local level.

A comparatively smaller literature assesses economy-wide employment effects by using input-output models. Wang et al. (2013) employ this methodology to estimate the impacts of CDM energy projects in China and showed that although CDM has caused direct job losses, it has also created indirect jobs. These impacts differed by project type: wind and biomass energy projects showed positive and significant effects in indirect employment generation that offset the negative effect in direct employment. In contrast, hydro projects had both direct and indirect job losses, particularly in the secondary energy industry and the mining industry. In the particular case of Brazil, no quantitative assessments have been conducted yet in the context of CDM. Using qualitative approaches and PDD data, Fernandez et al. (2014) found that CDM projects have succeed in delivering positive effects in local employment generation in the short-term (i.e., during construction and operation phases). However, indirect, induced or cross-sectoral employment effects are not assessed in this paper.

2.3. The impacts of Preferential Trade Agreements on emission reductions (paper 3)

Trade liberalization may affect the environment through three main channels (Grossman and Krueger 1991; Copeland and Taylor 2004); The first channel is the scale effect or expansion of economic activity due to trade, which leads to an increase in energy use and thus in emissions; the second channel is the composition effect, which explains how trade liberalization may alter domestic

production structure, the direction of this effect depends on country's comparative advantages in emission-intensive sectors and whether these sectors are expanding (contracting). Finally, the technique effect explains how trade may contribute to reduce emissions by improving the way of producing (and consuming) goods through enhanced availability of low-carbon goods and technologies. The overall effect of trade on emissions cannot be known *a priori*. This framework can be extended to greenhouse gas emissions (Antweiler et al. 2001).

Through the technique effect, trade liberalization may create new opportunities for emerging markets such as those on low-carbon or environmental goods and cleaner technologies through two mechanisms (Grossman and Krueger 1991): first, a tariff removal on these goods will reduce the costs of cleaner technologies, contributing to its disseminating and transfer; second, trade may also increase income levels and thus the demand for low-carbon goods. Moreover, trade liberalization may also generate incentives to producers to increase their production on low-carbon goods and thus export them (Claro and Lucas 2007). Some successful experiences of emerging countries with a strong environmental goods sector that also export them are South Africa in the mining industry or China in the PV and wind industry (Buchner et al. 2014).

Due to the increasing recognition of the potential of trade to contributing to sustainable development goals, preferential trade agreements may potentiate these effects in a positive way. PTAs hold a high potential to contribute to climate mitigation as they exhibit attributes of trade negotiations that could shape them as strong instruments (OECD 2007; Gehring et al. 2013; Morin and Jinnah 2018). First, the reduced number of participants may accelerate the bargaining processes; second, the direct reciprocity allows introducing sanctions and thus enhancing compliance. Third, they also allow flexibility for policy experimenting with the possibility of yearly re-negotiations. Finally, easing access and diffusion of environmental goods and technologies achieved may contribute to climate change mitigation objectives (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017).In the last two decades, the incorporation of environmental provisions in these agreements has been rising, not only in number but also in scope and level of stringency (Jinnah and Morgera 2013); this rise offers room for innovative climate-supportive trade rules to deal with mitigation targets (Holzer and Cottier 2015; Brandi 2017). Regarding empirical evaluations of preferential trade agreement with environmental provisions, the literature can be divided into quantitative and qualitative research. Most quantitative studies have focused on the NAAEC[22] or the environmental side agreement of the NAFTA and most of them have applied computable general equilibrium (CGE) models rather than econometric techniques. Some reasons for this selection are for instance the suitability of this framework to provide an economy-wide picture by including all economic sectors and thus incorporating these interdependencies into the analysis. This gives the possibility to estimate potential cross-sectoral spill-overs through market interaction.

Using a CGE model, Grossman and Krueger (1991) analyzed the compositional effect of the NAFTA on pollution (i.e., sulphur dioxide) in Mexico; results showed that there was no evidence of environmental degradation. In contrast, Gallagher (2004) argued that environmental conditions worsened in Mexico, leading to an increase in sulphur and carbon dioxide emissions. Similarly, using econometric techniques, Yu et al. (2011) also found a significant increase in emissions not only in Mexico but also in the US after 1994.

[22] The North American Agreement on Environmental Cooperation (NAAEC) is an environmental agreement between the US, Canada and Mexico. It came into effect in 1994. The NAAEC contains a declaration of principles and objectives regarding conservation and environment protection.

Dong and Whalley (2011) presented numerical simulations of carbon motivated regional trade agreements using a multi-regional CGE model[23]. They evaluated the impact of two trade policies: tariff reduction on low-carbon intensive goods, and external trade barriers or penalties against third countries that do not follow. Their main findings showed that tariff reductions have a positive but quantitatively small impact on emission reductions. Under penalties against third parties, effects are still small. The authors argued that agreements on low carbon intensive products may not reduce emissions globally if emission intensities of production differ sharply within and outside the region i.e., between signatory and non-signatory parties. Regarding qualitative studies, some have reported the acceleration of environmental reforms in some countries that negotiated PTAs with environmental provisions; that is the case of Singapore (FTA US-Singapore 2003); Chile (FTA US-Chile 2003) or Morocco (FTA US-Morocco 2004) (OECD 2007).

[23] This model covers trade for US, EU, China and the rest of the world. The high-emission sector is represented by the manufacturing sector, while the low-emission sector includes service and agriculture.

3. Methodology and data

This section presents the selected methodologies and data used to assess each research objective. It is divided into three sub-sections: the first part is focused on evaluating the first objective through an econometric model that estimates the impacts of CDM on development indicators in Brazil at the municipality level. The second part focuses on assessing the cross-sectoral employment effects of CDM across Brazilian municipalities through a dynamic panel model. Finally, the third sub-section presents a CGE model which assesses the impacts of preferential trade agreements on emission reductions.

3.1. Econometric approach: Matching and diff-in-diff techniques (paper 1)

In order to estimate impacts of CDM on selected development indicators, a difference-in-differences (DiD) approach combined with matching techniques is applied. This combined technique aims at comparing changes over time of an intervention group (municipalities with CDM) that is affected or treated to a group that is not (municipalities without CDM). Under this framework, there is a pre-treatment era (or pre-CDM) and a post-treatment era (post-CDM) and between these two periods the policy intervention takes place.

This combined method (DiD and matching) is an attractive option when using research design based on controlling for confounding because it has the advantage of eliminating potential unobserved differences between treated and non-treated observations that are time invariant and which cross-section matching estimators fail to eliminate (Smith and Todd 2005; Lechner 2011). Moreover, the matching procedure ensures that similar regions are compared as treatment and control group.

The matching is a non-experimental sampling method that produces a control group whose distribution of covariates is similar to that of the treated group (Khander et al. 2010). The idea is to find a similar control municipality (without CDM) to compare with a treated municipality (with CDM), thus to reduce selection bias and improve the balance between groups. Here, I perform a kernel matching, in which all treated units are matched with a weighted average of all controls and weights are inversely proportional to the distance between the propensity score of the treated and control groups[24]. After finding "good" matches for the treatment group, Average Treatment Effects on the Treated (ATET) are estimated. The ATET is the difference between the outcomes of the treated and the outcomes of the treated if they had not been treated.

Regarding the outcome indicators, a list is provided in Table 1. With respect to the covariates for the matching, I consider variables such as geography and weather, municipality size, economic conditions, physical infrastructure and accessibility by roads. Data is available at the municipal level for two periods: 2000 (baseline or pre-CDM) and 2010 (follow-up or post-CDM). As the follow up period is 2010, only municipalities with CDM projects implemented before 2010 were considered as treatment group. Impacts are estimated for four project types: hydro, biomass energy, landfill-gas and methane avoidance. Wind projects were not included because most CDM investments in projects under this category took place after 2010. I distinguished impacts among project types due to intrinsic differences (e.g., labor intensive vs. capital intensive technologies) and to establish comparisons in terms of effectiveness in influencing the outcome indicators.

[24] Advantages of using this estimator are (Baser 2006): first, since all controls are used in weighting, lower variance is achieved; second, it works better with large and asymmetrically distributed control data as it is in this case.

Data on covariates are available from the Brazilian Institute of Geography and Statistics (IBGE), data on CDM investments comes from the CDM Pipeline Analysis and Database of the United Nations Environment Programme (UNEP), while data on outcome indicators are provided by the United Nations Development Programme Brazil (UNDP Brazil), the Industry Federation of the State of Rio de Janeiro (Firjan) and the Brazilian Institute of Geography and Statistics (IBGE).

Table 1: List of outcome indicators (paper 1)

Variable	Unit	Source
Municipal Human Development Index (Overall MHDI)[25]	(0-1)	UNDP Brazil[1]
Municipal Human Development Index (Income MHDI)[26]	(0-1)	UNDP Brazil[1]
Firjan Municipal Development Index (Overall FMDI)[27]	(0-1)	Firjan[2]
Firjan Municipal Development Index (Labor and income FMDI)[28]	(0-1)	Firjan[2]
Per capita income	Reals	IBGE[3]
Percentage of poor households	%	IBGE[3]
Percentage of population vulnerable to poverty	%	IBGE[3]
Theil index (inequality indicator)	(0-1)	IBGE[3]
Unemployment rate	%	IBGE[3]

[1]/ United Nations Development Programme Brazil,
[2]/ Industry Federation of the State of Rio de Janeiro
[3]/ Brazilian Institute of Geography and Statistics

3.2. Econometric approach: Dynamic panel model (paper 2)

In order to assess the impacts of CDM projects on employment, we investigate effects on total and cross-sectoral employment across Brazilian municipalities with CDM projects using a dynamic panel regression model for period 2004-2014. The attractiveness of this method lies in the incorporation of an autoregressive component (or the lagged dependent variable) that allows for dynamics, which in turn contribute to recovering consistent estimates of other parameters in the model (Bond 2002). Moreover, other advantages of using this approach are the possibility to correct for unobserved heterogeneity, omitted variables bias as well as potential endogeneity problems (Bond et al. 2001).

[25] The overall MHDI is the average of three sub-indexes in the areas of income, education and longevity. It is calculated using data from the Demographic Censuses of 2000 and 2010, by the United Nations Development Programme Brazil (UNDP Brazil) in cooperation with the Brazilian Institute of Geography and Statistics (IBGE).
[26] The income MHDI represents the residents' income at the municipality level.
[27] The overall FMDI is the average of three sub-indexes in the areas of income, education and health; it uses data from official sources such as the Ministry of Labor and Employment, Ministry of Education and Ministry of Health and it is calculated by the Industry Federation of the State of Rio de Janeiro (Firjan).
[28] The labor and income FMDI is an average of five indicators that monitors and characterizes the formal job market at the local level. These five indicators are formal employment creation, labor market absorption, formal income creation, the average of formal wages and income inequality at the municipal level (Firjan 2015).

Table 2: Variables description (paper 2)

Variable	Description	Type	Source
Total employment growth rate	Annual growth rate total employment (municipality)	Dependent	MTE[1]
Employment share in the industry sector	Annual employment share in the industry sector (municipality)	Dependent	MTE[1]
Employment share in the agricultural sector	Annual employment share in the agricultural sector (municipality)	Dependent	MTE[1]
Employment share in the services sector	Annual employment share in the services sector (municipality)	Dependent	MTE[1]
Employment share in the construction sector	Annual employment share in the construction sector (municipality)	Dependent	MTE[1]
Employment share in the commerce sector	Annual employment share in the commerce sector (municipality)	Dependent	MTE[1]
CDM	Dichotomous variable: 0 = municipality without a CDM project at time *t* 1 = municipality with a CDM project at time *t*	Explanatory	UNEP[2]
CER credits	Dichotomous variable: 0 = municipality with a CDM project that did not generate CER credits at time *t* 1 = municipality with a CDM project that generated CER credits at time *t*	Explanatory	UNEP[2]
Time-dummy: CER crisis	Dichotomous variable: 0 = Before CER crisis (2004-2012), 1 = After CER crisis (2013-2014)	Explanatory	UNEP[2]
Total real GDP growth rate	Annual total GDP growth rate (municipality)	Explanatory	IBGE[3]
Industry real GDP growth rate	Annual GDP growth rate in the industry sector (municipality)	Explanatory	IBGE[3]
Agriculture real GDP growth rate	Annual GDP growth in the agricultural sector (municipality)	Explanatory	IBGE[3]
Service real GDP growth rate	Annual GDP growth in the service sector (municipality)	Explanatory	IBGE[3]

[1]/ Brazilian Ministry of Labor and Employment
[2]/ United Nations Development Programme Brazil
[3]/ Brazilian Institute of Geography and Statistics

Table 2: Variables description (cont.) (paper 2)

Variable	Description	Type	Source
Population growth rate	Annual population growth (municipality)	Explanatory	IBGE[3]
Total real GDP growth rate	Annual total GDP growth (federate state)	Explanatory	IBGE[3]
Industry real GDP growth rate	Annual GDP growth in the industry sector (federate state)	Explanatory	IBGE[3]
Agriculture real GDP growth rate	Annual GDP growth in the agricultural sector (federate state)	Explanatory	IBGE[3]
Service real GDP growth rate	Annual GDP growth in the service sector (federate state)	Explanatory	IBGE[3]

[3]/ Brazilian Institute of Geography and Statistics

The dynamic panel model is estimated using the Generalized Method of Moments (GMM) approach (Arellano and Bond 1991). Equation (1) describes this model (Bond 2002), where $y_{i\,t-1}$ is the autoregressive term, x_{it} is a set of explanatory variables which could also include a lagged structure of them; ρ_i represents unobserved individual-specific effects, while ε_{it} is an error term.

$$y_{it} = \alpha\, y_{i\,t-1} + \beta\, x_{it} + \rho_i + \varepsilon_{it} \quad (1)$$

The unobserved individual-specific effects are correlated with the autoregressive term by construction; thus, the Arellano-Bond estimator is constructed by first differencing to remove the panel-level effects and using instruments to form moment conditions. Lagged values of the dependent variable are used to form the GMM-type instruments. One important model assumption is that the error terms are independent across individuals, so they are serially uncorrelated.

To explore cross-sectoral effects, we evaluate impacts on sectoral employment shares for the following sectors: industry, agriculture, services, construction and commerce. Two project categories are analyzed: hydro and methane avoidance[29]. Regarding explanatory variables relevant for general trends in employment generation, both economic and demographic indicators at the municipal and federal state the municipal level are included. Data on employment are available from the Brazilian Ministry of Labor and Employment (MTE) from the Annual Report on Social Information (RAIS), data on CDM investments comes from the CDM Pipeline Analysis and Database of the United Nations Environment Programme (UNEP), while data on explanatory variables are provided by the Brazilian Institute of Geography and Statistics (IBGE). A detailed description of all variables is displayed in Table 2.

[29] Other project types (such as wind, biomass and landfill-gas) were not included in the analysis due to sample size issues.

3.3. CGE model (paper 3)

To investigate the macroeconomic effects of a preferential trade agreement with climate-related provisions between Brazil and the European Union, a CGE model is applied. This framework allows assessing macroeconomic impacts by extending the analysis to all sectors in the economy and giving the possibility to estimate potential spill-overs among them through market interaction. For this purpose, a multi-regional multi-sectoral CGE model based on Nabernegg et al. (2017) and Schinko et al. (2014) is used. A novelty in this CGE model is the disaggregation of the electricity sector for Brazil and the EU into different production technologies (i.e., hydro, wind, biomass, solar, natural gas and fuel oil) including transmission and distribution; this disaggregation allows investigating the impacts of climate and energy related instruments in the selected scenarios.

This CGE model represents the structure of an economy by national and international trade flows organized by 10 regions[30] and 25 economic sectors. In each region agents interact on the supply and demand side of different markets. The regional household is endowed with the primary factors of labor, capital and natural resources. These primary factors are used in the domestic production process uses also intermediate inputs from all other sectors. The primary factors are assumed to be perfectly mobile between the different sectors, but immobile between regions.

Sectoral firms are assumed to produce under perfect competition and provide their produced output for exports to other regions or domestic supply. The different degree of substitutability between sectoral inputs is captured by nested constant elasticity of substitution (CES) functions for each sector. For the preferences between domestically produced and imported products the Armington assumption (Armington, 1969) is followed, which treats sectoral products from different regions as imperfect substitutes. Finally, the domestic supply is demanded by other firms as intermediate inputs and as final demand of the regional household. Households optimize their consumption level given their income from labor, capital, and natural resources. Final demand (by households and the government) is represented by nested CES functions in the model.

Data on installed and generation capacity by technology come from the Brazilian Energy Research Office (EPE 2017a, 2017b), while data on Levelised Cost of Electricity (LCOE) for each technology are from Jong et al. (2015). Data on investment costs are provided by Jong et al. (2015) and Silva et al. (2016) to assign the corresponding capital inputs as share of total inputs for each technology. For model calibration, it is used economic data from the Global Trade Analysis Project (GTAP) Version 9 (Aguiar et al. 2016). Benchmark year is 2011. Regarding substitution elasticities for sectoral production functions, these are specified from different studies (Aguiar et al. 2016; Beckman and Hertel, 2010; Okagawa and Ban, 2008).

Regarding policy scenarios, a description is provided in Table 3. In the first scenario (Preferential Trade Agreement or PTA), the effects of a reduction in trade barriers in environmental goods and technologies between the EU and Brazil are assessed. Specifically, it is assumed that the tariff on imports of sectoral outputs of Machinery and equipment (Teo) and Electronic equipment (Tec) from Europe that are used in the renewable electricity sectors of Brazil is removed. This policy should increase the installation of renewable electricity capacities using European technology at reduced costs.

[30] These 10 regions are: Brazil, the European Union, Mercosur (Argentina, Uruguay, Paraguay), the United States of America, China, Latin America, Oil/gas countries, Asia-Oceania, Africa and the Rest-of-the World.

Under the second scenario (promotion of Foreign Direct Investment or FDI), it is assumed now that the preferential trade agreement includes an increase in investments in new renewables (i.e., other than hydro) to reach a share of 23% in the electricity generation mix of Brazil, which corresponds to the Brazilian NDC for 2030. The level of European FDI is consistent with this target. Moreover, the capital effectiveness of FDI compared to the Brazilian capital input is increased, which indicates lower European interest rates and continued technological progress.

Table 3: Description of policy scenarios (paper 3)

	Scenario	Description	Model implementation
1	PTA	• Preferential trade agreement (PTA) with climate-related provisions • Zero-tariff on low-carbon goods (inputs and cleaner technologies)	• Direct import flow modelling of technology inputs from the Machinery and equipment (Teo) and Electronic equipment (Tec) sectors in the renewable electricity sector • Zero tariff on EU imports of electricity technology in the Teo and Tec sectors
2	FDI	• Foreign direct investment (FDI) promotion in climate-related sectors (i.e., FDI targeting the Brazilian electricity sector)	• Sector specific capital endowments for the renewable electricity sectors at constant Baseline level • Exogenous substitution of domestic sector specific capital with European capital input to achieve NDC target of 23% RES w/o hydro. • Exogenously increased European capital effectivity reflecting PTA circumstances and technology improvements (especially in Solar)
3	DEP	• Domestic energy policy (DEP) in Brazil	• Revenue neutral combination of increased fossil fuel taxes and reduced renewable electricity taxes • The additionally generated tax revenue is used as subsidy to the renewable electricity sector

Finally, in the third scenario (Domestic Energy Policy or DEP), the effects of a change in domestic energy taxes in Brazil is quantified. A combination of fiscal measures (increase in fossil fuel taxes and reduction of renewable electricity taxes) is implemented. This tax regime is set up as revenue neutral; this means that the revenues obtained from the increase in fossil fuel taxes finance subsidies for renewable electricity production. Here it is assumed that the relationship between fossil fuel and renewable electricity taxes is adjusted towards the relationship in Europe. While in Brazil fossil fuel use in industry and electricity production is currently much less taxed than electricity from renewable sources, in the EU there is a much smaller gap between these tax rates on fossil and renewable sources of energy (OECD 2018).

4. Publications

This section attaches the three papers that contribute to answering the three research objectives of this dissertation.

4.1. Paper overview and scientific contributions

As mentioned earlier, this dissertation consists of three papers. A brief description of each paper and respective research contributions are provided below. In addition, Table 4 gives an overview of the papers, publication status as well as the role of the author of this dissertation for each of them.

Paper 1

The first papers seeks to determining to what extent CDM investments have provided Brazilian municipalities with sustainable development benefits by measuring the impact on development and poverty indicators. This research contributes to this strand of the literature in four ways: first, most assessments have applied qualitative methods and data based on expected effects; in contrast, this study quantifies the aggregated impact of CDM projects. Second, available studies on the impacts of CDM on poverty alleviation are still very limited (Dirix 2016), so this research also aims at contributing to fill this gap in this specific niche. In addition, impacts on inequality are explored; this variable has been barely analyzed in the empirical literature (Mori-Clement 2018). Third, I estimate impacts across Brazilian municipalities (within-country analysis); since each country must define its own sustainable development criteria according to its national priorities, an analysis at the sub-national scale is more relevant and appropriate than cross-country comparisons. Finally, this paper investigates whether renewable energy projects (i.e., hydro and biomass energy) have positive effects on sustainable development, by contrasting the effects triggered by this project type with waste handling and disposal projects (i.e., landfill gas and methane avoidance).

Paper 2

The objective of this paper is to contribute to understand the impacts of CDM projects on development, with a focus on assessing effects on cross-sectoral employment at the municipal level in Brazil. This study addresses three important research gaps: first, most assessments have applied qualitative methods to evaluate effects; in contrast, this study applies an econometric approach using empirical data to estimate the impact of CDM projects on local employment. Second, most papers have investigated the achievements of CDM projects on employment generation in the renewable energy sector. However, evaluations of the economic impacts of waste handling and disposal projects at the local level are scarce (Cruz et al. 2017). In this paper, I address this gap by providing empirical evidence on employment effects triggered by methane avoidance projects and comparing them to the effects generated by renewable energy projects (i.e., hydro). Third, I focus on estimating effects on cross-sectoral employment by using empirical data that does not draw on the PDD but uses municipal data provided by official statistical sources.

Paper 3

This paper discusses the potential and the impacts of a preferential trade agreement with climate-related provisions between Brazil and the European Union on emission reductions and economic performance by looking into three scenarios: (i) removal of import tariffs on renewable energy

equipment; (ii) promotion of climate-related foreign direct investments and (iii) domestic energy policy that combines fossil-fuel taxes and renewable subsidies. This study contributes to the literature on new climate mechanisms as follows: first, despite of the theoretical potential of trade agreements to deal with GHG mitigation, empirical analyses are still very limited. Here, this analysis investigates how trade arrangements could be designed to achieve mitigation targets, while stimulating economic performance in emerging economies. Second, although there are some evaluations of the economic effects of a trade agreement between Brazil and the European Union, this research represents the first study that evaluates climate-related impacts. Given the running negotiations of a PTA between MERCOSUR and the European Union, these findings could contribute to the specific design of climate provisions. Finally, this investigation may contribute to the broad debate on the design of new climate mechanisms in the Post-Kyoto era.

Table 4: Paper overview and author contributions

Paper 1: ***Impacts of CDM projects on development: improving living standards across Brazilian municipalities?***

Journal: World Development

Status: Published

Authors	**Concept**	**Analysis**	**Writing**	**Total**
Mori-Clement, Y.	100%	100%	100%	**100%**

Paper 2: ***Do Clean Development Mechanism projects generate local employment? Testing for sectoral effects across Brazilian municipalities***

Journal: Ecological Economics

Status: Minor revisions, resubmitted

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Paper 3: Can preferential trade agreements enhance renewable electricity generation in emerging economies? A model-based policy analysis for Brazil and the European Union

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Status: Preparation for submission to the journal "Climate Policy"

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Regarding my specific contribution to each paper, as a single author of Paper 1, I developed the research idea; reviewed the empirical literature, collected and prepared the data for the analysis; chose and conducted the econometric analysis and independently wrote the manuscript. For Paper 2, I collaborated in developing the concept and research objective; collected and prepared the data for the

analysis; chose and conducted the econometric approach and collaborated in the interpretation of results, discussion and conclusions. In the case of Paper 3, I collaborated in developing the research idea, objectives and motivation. For the analysis, I collected data for the CGE model (e.g., LCOE data, investment costs by technology, installed capacity by technology, investment trends in renewable in Brazil) and collaborated in scenarios definition. For the writing part, I reviewed the theoretical framework of the impacts on trade on climate change; the empirical literature on the impacts of trade agreements, their main findings and applied methodologies; the energy policies promoting renewable and fossil fuels in Brazil; and collaborated in the elaboration of the discussion and conclusions section.

4.2. Paper 1

Mori-Clement, Y. (2018): Impacts of CDM projects on development: improving living standards across Brazilian municipalities? *World Development*, https://doi.org/10.1016/j.worlddev.2018.06.014

Impacts of CDM projects on sustainable development: improving living standards across Brazilian municipalities?

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Abstract

The goal of the Clean Development Mechanism (CDM) is both emission reduction and sustainable development, but while emission reductions generate revenues for the project developer, no such benefit results from the achievement of sustainable development. The objective of this research is therefore to analyze to which extent CDM investments have led to sustainable development benefits, and whether there is a difference in these effects between renewable energy and waste handling and disposal projects. Complementary to existing studies, which are based on potential effects reported ex-ante by project developers, this paper aims at quantifying impacts of CDM projects on sustainable development based on empirical data. Using data for years 2000 (pre-CDM) and 2010 (post-CDM) for Brazilian municipalities, this paper combines difference-in-differences assessment with matching techniques to identify the effect of CDM investments on development and poverty indicators by distinguishing for four project's types: hydro, biomass energy, landfill gas and methane avoidance. Results show that CDM project types have stimulated local income and labor opportunities but only hydro projects have contributed to reduce poverty at the municipal level for the period analyzed.

Keywords: Clean development mechanism, sustainable development, renewable energy and waste handling and disposal projects, Brazil, development and poverty indicators, difference-in-differences and matching techniques

1. Introduction

According to the twofold objective of the CDM instrument, this mechanism was designed not only "to help developed countries fulfill their commitments to reduce emissions", but also "to assist developing countries in achieving *sustainable development"*. What sustainable development means or how this concept is or should be understood under this framework is (still) arguable or not clear (Banuri and Gupta 2000; Schneider 2007). Under the Marrakesh Accords (2001), each host country must decide what aspects of sustainable development should be accomplished when implementing CDM projects in its territory.

Concerns regarding the effective achievement of this objective have emerged and been discussed even before the official launch and implementation of the CDM instrument in host countries (See: Banuri and Gupta 2000; Kolshus et al. 2001). Moreover, potential conflicts and trade-offs between the two CDM objectives may arise when trying to fulfill both targets through the implementation of CDM projects (Kolshus et al. 2001; Sutter 2003). Since the CO_2 emission reductions is the only objective that is rewarded by the market through the generation of Certified Emission Reduction (CER) credits, the CDM instrument does not create by itself adequate incentives to fulfill the sustainable development objective (Ellis et al. 2007; Paulsson 2009).

Moreover, the Designated National Authorities (DNAs), the entities in charge of approval of CDM projects in the host country, might have incentive to relax the stringency of the sustainable development requirements in order to attract more CDM investors (May et al. 2004; Olsen 2007; Muller 2007), thus reinforcing the trade-off between the two objectives. Although very few developing countries have developed their own requirements for hosting CDM projects, these scarce efforts lose strength due to the lack of monitoring and verification of compliance of the sustainable development criteria (Wang et al. 2013; Crowe 2013). In addition, the absence of international standards for sustainable development assessment of CDM projects as well as the missing obligation for the host countries to verify project's achievements in this aspect (in contrast to the existing strict monitoring of CO_2 emission reductions) might exacerbate the trade-off (Olsen and Fenhann 2008).

Although several definitions of sustainable development have been discussed in the literature, this concept can be generally understood as the intersection of three dimensions or pillars (WCED 1987):

social equality, economic growth and environmental protection. Under the framework of CDM projects, the sustainable development criteria should be based on country-specific development priorities with focus on these three dimensions (Olhoff et al. 2012).

Although several earlier studies have attempted to highlight the potential of CDM projects in contributing to sustainable development in host countries (Richards 2003a; Troni et al. 2002; Smith and Scherr 2002), other studies have also argued that this target was in reality more a hypothesis than a real causality effect (Markandya and Halsnaes 2002; Kolshus et al. 2001). Since the CDM is a market instrument that targets least-cost mitigation projects rather than poorest communities, the sustainable development objective was expected to be overtaken by the reduction emission goal. Moreover, the assessment of any sustainable development impact due to CDM activities were left to host countries, so that very little in the Accord ensured that these benefits were effectively attained (Begg et al. 2003).

Those studies, that discussed the theoretical ability of CDM projects in generating synergies between environment and local livelihood improvements, have identified high potential in renewable energy projects and used the framework that links the provision of clean energy to local sustainable development to explain causal effects (Troni et al. 2002). Under this framework, the access to energy is a key vehicle that drives sustainable development through the provision of basic needs (e.g.: cooked food, piped water), realization of productive activities (e.g.: manufacturing, commerce) and protection of local environment; thus generating improvements in livelihood conditions (UNDP 2000, 2005).

In the context of CDM, the effects of small-scale rural renewable energy projects in local sustainable development have been translated into the opportunities generated by improved access to clean energy services by poor households through income diversification due to enterprise development and employment generation, improved health due to access to cleaner water as well as reduced fuel wood consumption, education due to lightning appliances as well as time available for studying at night, gender benefits due to less time collecting firewood and water by women, among other benefits (Troni et al. 2002, Brunt and Knechtel 2005). In a similar way, effects in sustainable development have been analyzed in other sectors such as forestry (Smith and Scherr 2002). Therefore,

distinguishing impacts by project type is relevant to understand the nature and causality of effects at the local level.

In the particular case of Brazil, the third largest host country worldwide in terms of the number of CDM projects, its Designated National Authority (DNA) has explicit criteria to determine the contribution of CDM projects to sustainable development in the project area (ICGCC 2003) as well as it has conducted very stringent evaluation processes (Hultman et al. 2012); however, there are no indicators or specific measurement tools for monitoring and verifying compliance of the sustainable development goal established officially by the corresponding DNA (Americano 2008).

The objective of this research is to determine to what extent CDM investments have provided Brazilian municipalities with sustainable development benefits by measuring the impact on development and poverty indicators. This research contributes to this strand of the literature in four ways: first, most assessments have applied qualitative methods and data based on expected effects; in contrast, we aim at quantifying the aggregated impact of CDM projects by combining difference-in-differences assessment with matching techniques using empirical data for the years 2000 (pre-CDM) and 2010 (post-CDM). Second, available studies on the impacts of CDM on poverty alleviation are still very limited (Crowe 2013; Dirix et al. 2016), so this research also aims at contributing to fill this gap in this specific niche. In addition, we also explore impacts on inequality and unemployment, variables barely analyzed in the empirical literature. Third, this study estimates impacts across Brazilian municipalities, or within-country analysis; since each country must define its own sustainable development criteria according to its national priorities, an analysis at the sub-national scale (in this case, at the municipal level) is more relevant and appropriate than cross-country comparisons. Finally, this paper investigates whether renewable energy projects (i.e.: hydro and biomass energy) have positive effects on sustainable development, by contrasting the effects triggered by this project type with waste handling and disposal projects (i.e.: landfill gas and methane avoidance).

This paper is organized as follows: sections 2 presents a review of the literature on the impacts of CDM investments on sustainable development in host countries, section 3 describes the situation of CDM projects in Brazil, while section 4 describes the data and the methodological approach. Results

of the regression analysis are presented in section 5, while policy implications and conclusions are inferred in section 6.

2. Empirical literature review

The empirical literature on the impacts of CDM projects can be divided into two main groups: the first group encompasses those studies that evaluate the effectiveness of CDM projects in reducing CO_2 emissions[31], while the second group assesses the impacts on sustainable development in host countries. In this section, the literature review focuses on this last group by presenting an overview of aspects/dimensions, proxy variables, main findings, methodologies and data used to determine the CDM achievements in sustainable development. As this study analyses the impacts on development and poverty indicators, we review empirical studies on poverty alleviation and discuss their main findings.

Research on the impacts of CDM on sustainable development has assessed effects using several group indicators that encompass the most relevant areas of any sustainable development strategy: social, economic and environmental. Some common indicators used to evaluate the economic aspects of sustainable development achievements of CDM projects are households' and/or per capita income (Subbarao and Lloyd 2011; Bayer et al. 2013) as well as generation of local employment (Sutter and Parreño 2007; Olsen and Fenhann 2008; Alexeew et al. 2010; Subbarao and Lloyd 2011; Wang et al. 2013) and technology transfer (Schneider et al. 2008; Dechezlepretre et al. 2009; Seres et al. 2009, 2010; Alexeew et al. 2010; Costa-Junior et al. 2013; Lema and Lema 2013).

With respect to the social aspect of sustainable development, some studies have focused on analyzing impacts of CDM projects on health, education (Subbarao and Lloyd 2011) and poverty alleviation (Sirohi 2007; Subbarao and Lloyd 2011; Crowe 2013). Regarding this last group, studies available on this topic are still very limited (Crowe 2013; Dirix et al. 2016). Although poverty alleviation is not explicitly part of the CDM mission, this aspect is integral of any sustainable

[31] Findings from this first group of studies are not conclusive; while some studies do not support any contribution of CDM to reducing CO_2 (Schneider 2007; Zhang and Wang 2011), others have confirmed a significant decline associated with CDM projects (Huang and Barker 2012).

development strategy; therefore, CDM projects should deliver a minimum of pro-poor co-benefits (Sirohi 2007; Dirix et al. 2016).

Finally, in the environmental sphere, research focuses on the impacts on environmental amenities such as air, water or soil (Sutter and Parreño 2007; Olsen and Fenhann 2008; Alexeew et al. 2010; Subbarao and Lloyd 2011). Additionally, some studies have applied scores based on set of indicators (Nussbaumer 2009; Alexeew et al. 2010; Subbarao and Lloyd 2011; Drupp et al. 2011) and indexes[32] (He et al. 2014) that represent the multidimensionality of the sustainable development concept.

With respect to findings, these are not conclusive (Shishlov and Bellassen 2012; Wang et al. 2013; Michaelowa et al. 2014). Some studies have reported positive contributions to local sustainable development in terms of increasing income (Bayer et al. 2013) and employment generation (Olsen and Fenhann 2008; UNFCCC 2011; Wang et al. 2013), improved air quality (Olsen and Fenhann 2008), and successful technological transfer (Schneider et al. 2008; Seres et al. 2009, 2010). On the other hand, there is a strand of the empirical literature that found no impacts at the local level associated with the implementation of CDM projects (Sutter and Parreño 2007; Headon 2009; Alexeew et al. 2010; Drupp 2011; Subbarao and Lloyd 2011; Costa-Junior et al. 2013; Lema and Lema 2013). In the particular case of poverty alleviation, some authors argued that CDM projects may have the potential to deliver benefits to poor income groups (Sirohi 2007; Capoor and Ambrosi 2009; Wood 2011); however, findings do not support this strongly (Sirohi 2007; Subbarao and Lloyd 2011; Crowe 2013). According to these studies, CDM projects had very limited or no impact in reducing local poverty.

One explanation for the absence of impacts is that there is an inherent conflicting relationship between the two CDM objectives (Olsen 2007). This hypothesis of the trade-off between the CDM objectives has been empirically tested by few studies that also have analyzed impacts of CDM on sustainable development; all of them have identified a trade-off in favor of the cost-efficient emission reduction target (Schneider 2007; Sutter and Parreño 2007; Pearson 2007; Alexeew et al. 2010). A second explanation states that there is a "race to bottom" in which host countries have lowered their

[32] He et al. (2014) used the Sustainability-adjusted Human Development Index (Pineda 2012), which is an extension of the Human Development Index (HDI).

sustainable development requirements to attract more CDM project developers (Drupp 2011; Alexew et al. 2010). In addition, as sustainable development priorities and assessment criteria vary across host countries as well as there is no universal way to assess impacts, it is expected to observe variation in targets (Subbarao and Lloyd 2011).

Regarding the methodologies applied to assess CDM impacts on sustainable development, most studies have adopted qualitative rather than quantitative approaches (Wang et al. 2013). Some examples of qualitative approaches are checklists (Olsen and Fenhann 2008), scoring pattern methods (Subbarao and Lloyd 2011), content analysis (Costa-Junior et al. 2013) and the Multi Criteria Assessment (MCA) method and its further adaptations (e.g.: the Multi-Attribute Assessment of CDM or MATA-CDM -Sutter 2003). These studies have relied, in almost all cases, on information provided by the Project Design Document (PDD) of each CDM project (Lema and Lema 2013; He et al. 2014).

The guideline for the design of PDD files requires a section that describes the potential impacts of the project on sustainable development. In this section, project developers must highlight the positive effects on one or more dimensions; most common benefits describe are environmental and health (e.g. reduction of air pollutants and/GHG emissions), technology transfer or local job opportunities (e.g. during construction and operation phases)[33]. In general, this description of the sustainable development benefits tends to be vague without clarifying causality effects at the local level as a result of project's activities. Although some expected impacts can be understood directly (e.g. human health improvements as a consequence of reduction in air pollution), other effects might be complex due to their interaction with myriad of variables and sectors (e.g. indirect job generation or income diversification as a result of access to cleaner energy sources). Another important drawback of using data from the PDD is that it only reflects potential or expected results and thus, it does not capture real impacts that took place after implementing the CDM project as it is only an ex-ante analysis (Nussbaumer 2009).

Very few studies have attempted to quantify impacts of CDM projects using empirical data from statistical sources. For instance, Input-Output models have been used to estimate employment flow

[33] In very few cases, it is mentioned that part of project's income will be allocated to the municipal government, which in theory would designate it to local education and health.

across sectors at the sub-national level in China (Wang et al. 2013) and a few panel models have tried to estimate the determinants of CDM project's distribution within-country (Bayer et al. 2013) or to assess the fulfilment of the sustainable development goal through cross-country comparisons (He et al. 2014)[34]. For Brazil, there has been no quantitative assessment conducted yet, but qualitative techniques using data from the PDD as well as stakeholders' interviews have been applied to determine impacts. For instance, Fernandez et al. (2014) analyzed the impacts on local employment, health, education and empowerment of vulnerable people; while Junior-Costa et al. (2013) focused on successful transfer and promotion of cleaner technologies using data from the PDDs as well as case studies. According to these studies, CDM projects have succeed in delivering economic results in the short-term (i.e.: employment during construction and maintenance phase, increasing local income), but failed to promote long-term benefits in some Brazilian states.

3. The CDM in Brazil

Brazil is the third largest country worldwide regarding the number of registered CDM projects. The first project was registered in 2004, a landfill gas project located in the municipality of Nova Iguacú in Rio de Janeiro federate state, and until 2015 around 338 projects have been registered in the pipeline (UNEP 2016). CDM projects in Brazil can be divided into two main categories according to their sectoral: renewable energy projects (61%) and waste handling and disposal projects (34%). The rest (5%) went to projects in the chemical and manufacturing industries. Within the renewable energy sector, hydro (45%), wind (27%) and biomass energy (22%) are the main project's types. Most predominant subtypes in this sector are: run-of-river hydroelectric power (hydro projects), wind (wind projects) and bagasse power (biomass energy projects). In the waste handling and disposal sector, main types are methane avoidance (56%) and landfill gas (44%). Regarding subtypes in this sector, most important categories are landfill flaring, landfill power (landfill gas projects), and manure (methane avoidance).

[34] Bayer et al. (2013) identified three main determinants of CDM investments across provinces in China for period 2004-2009: high electricity consumption, low per capita income and absence of FDI inflows. He et al. (2014) used the Sustainability-adjusted Human Development Index (SHDI) to determine contributions of CDM to this aspect using a sample of 58 host CDM countries for period 2005-2010.

With regard to the size, almost 70% of the projects are large scale[35], while the remaining 30% are small scale projects. In the renewable energy sector, in a similar way, 70 % are large; in particular, 100% of the wind projects are of large scale. In the waste handling and disposal sector, 61% are large projects; where all landfill gas type projects are large, while the methane avoidance at almost 80%. In terms of geographical distribution of CDM projects in Brazil: macro regions where CDM projects were implemented are the South-east with 39.3% of the total; the North-east with 21.6%, the South with 19.2% and the Central-west with 14.5%. Few projects (5.3%) were implemented in the North (Amazonian), a region characterized by high forest density. Regarding renewable energy projects, more than 50% are located in the South-east and South region (30.4% and 22%, respectively), and 28% in the North-east.

One interesting finding is that almost 80% of the CDM projects in the North-east are investments in the renewable energy sector; this reflects the high potential of this region to host energy projects such as hydro and wind. Regarding waste management and disposal projects, 51% of total are located in the South-east, 18% in Central-west and 17% in the South. The distribution of CDM projects reflects a general division of the country, where the South and South-east are much more developed and industrialized than the north (Fernandez et al. 2012).

At the municipal level, the distribution of CDM projects by macro region is displayed in table 1. At the national level, 7.6% (or 425 municipalities) has at least one CDM project that was implemented during period 2004-2015. This number exceeds the total number of registered CDM projects (338) because, in some cases, some project's activities included more than one municipality, therefore the geographical scope could go beyond that area. The macro region with the lowest percentage of municipalities with CDM projects with respect to its total is the North-east (2.8% or 51 municipalities), while the region with the highest percentage is the Central-west (15% or 72 municipalities), followed by the South-east (10.1% or 168 municipalities).

[35] Large and small scale projects follow different rules, but in general, requirements are less strict in the last case. To fall under the category of small project, for instance, a project in renewable energy must be 15MW or less of output per year; in the case of energy efficiency projects, these must reduce energy consumption by 60 Gigawatt hours per year or less. For other categories, these must reduce up to 60,000 tons of CO_2 annually (Carbon Market Watch).

Characterizing those municipalities with CDM investments, table 2 displays descriptive statistics that compare means of the CDM sample with means at the macro region level. In general, CDM municipalities' depicts lower rates of rural population, higher GDP share in the industry sector and higher percentage of households with access to water and electricity.

Table 1
CDM in Brazil: project type and distribution across municipalities by macro region
(Period: 2004-2015)

Region	Number of CDM projects	%	CDM project type						Total municipalities	Municipalities with CDM	%
			Hydro	Wind	Biomass energy	Landfill gas	Methane avoidance	Other			
North	18	5.3	9	0	2	3	1	3	449	25	5.6
North-east	73	21.6	5	47	6	8	4	3	1793	51	2.8
Central-west	49	14.5	26	0	2	0	20	1	466	70	15
South-east	133	39.3	26	0	29	33	27	18	1668	168	10.1
South	65	19.2	28	9	7	7	12	2	1188	110	9.3
Total	**338**	**100**	**94**	**56**	**46**	**51**	**64**	**27**	**5564**	**425**	**7.6**

Source: UNEP, IBGE.

Table 2
Characterization of municipalities with CDM projects by macro region
(Year: 2000)

Region	Rural population (%)		Share of industry (%)		Households with access to water (%)		Households with access to Electricity	
	CDM	Total	CDM	Total	CDM	Total	CDM	Total
North	41.1%	48.7%	12.0%	8.4%	45.9%	33.9%	70.1%	65.2%
North east	45.6%	50.3%	19.0%	11.4%	42.3%	39.9%	82.2%	77.5%
Central-west	28.6%	32.8%	14.0%	13.2%	79.8%	76.7%	91.4%	88.8%
South-east	22.8%	30.4%	23.4%	18.1%	90.9%	87.2%	97.1%	94.9%
South	39.7%	46.0%	20.8%	16.9%	89.3%	86.6%	95.3%	95.6%

Source: IBGE

With respect to sustainable development, the Brazilian DNA has explicit criteria to determine the contribution of CDM projects to sustainable development. These criteria include six main indicators: contributions to local environmental sustainability, the improvement of working conditions, net

employment creation, fair income distribution, technology development, and regional integration and linkages with other sectors (ICGCC 2003). Although Brazil had one of the most stringent DNA processes (Hultman et al. 2012), the DNA has not established any indicator or measurement tools for monitoring and evaluating the contribution of CDM projects in the territory to local sustainable development (Americano 2008).

4. Methodological approach

4.1. Data

In the context of CDM projects, the sustainable development criteria reflect country-specific development priorities. Due to limited scope of this study and challenges in data constraints, we try to assess impacts of CDM projects on two dimensions: the economic and social, through the outcome indicators listed in Table 3:

Table 3
List of outcome indicators

Variable	Unit	Source
Municipal Human Development Index (Overall MHDI)	(0-1)	UNDP Brazil[1]
Municipal Human Development Index (Income MHDI)	(0-1)	UNDP Brazil[1]
Firjan Municipal Development Index (Overall FMDI)	(0-1)	Firjan[2]
Firjan Municipal Development Index (Labour and income FMDI)	(0-1)	Firjan[2]
Per capita income	Reals	IBGE
Percentage of poor households	%	IBGE
Percentage of population vulnerable to poverty	%	IBGE
Theil index (inequality indicator)	(0-1)	IBGE
Unemployment rate	%	IBGE

[1] Data from the IBGE demographic census.
[2] Data from official statistics areas from several ministries.

We have included in the analysis two development indexes: the overall Municipal Human Development Index (MHDI) and the overall Firjan Municipal Development Index (FMDI), as well as their respective income and labour/income sub-indexes. Although both indexes (MHDI and FMDI) might present some similarities (both are the average of three sub-indexes in the areas of income,

education and health), there are some important differences in terms of methodology of calculation and data sources. For instance, in the case of the income sub-indexes, the income MHDI is basically the residents' income in a certain location, while the labour and income FMDI is an average of five indicators[36] that monitors and characterizes the formal job market at the local level. In a similar way, both education[37] and health[38] sub-indexes are calculated using different methodologies. Regarding data sources, the MHDI is calculated using data from the Demographic Censuses of 2000 and 2010, by the United Nations Development Programme Brazil (UNDP Brazil) in cooperation with the Brazilian Institute of Geography and Statistics (IBGE), while the FMDI uses data from official sources such as the Ministry of Labour and Employment, Ministry of Education and Ministry of Health and it is calculated by the Industry Federation of the State of Rio de Janeiro (Firjan).

Other outcome indicators such as per capita income, poverty indicators (i.e., percentage of poor households), Theil index and unemployment rates were also obtained from the 2000 and 2010 census data (UNDP Brazil) in cooperation with the IBGE. Regarding data on CDM investments, this information comes from the CDM Pipeline Analysis and Database of the United Nations Environment Programme (UNEP). With respect to the unit of analysis, we look at the municipality level, which is the smallest unit of disaggregation available in data for Brazil. The analysis includes only CDM projects that are large scale, assuming that this size may have an influence area whose effects could reach the municipality level. Data is available for two periods: 2000 (baseline or pre-CDM) and 2010 (follow-up or post-CDM).

4.2. Methodology

In order to estimate impacts of CDM on selected outcome indicators, a difference-in-differences (DiD) approach combined with matching techniques was applied. The DiD is a technique commonly

[36] These five indicators are intended to reflect formal employment creation, labor market absorption, formal income creation, average formal wages and income inequality at the municipal level (Firjan 2015).
[37] The MHDI education sub-index is composed of two indicators: educational level of the adult population and educational flow of young people, while the FMDI education sub-index is the average of seven sub-indexes: kindergarten enrollment rates, elementary school drop-out rates, elementary education age-grade
[38] The MHDI longevity sub-index is a measure of life expectancy at birth, while the FMDI health sub-index is focused on primary health care and mortality. This last sub-index is the average of four indicators with equal weight: average pre-natal visits, undefined cause deaths, infant mortality by avoided causes and hospital admission linked to lack of preventive care (Firjan 2015).

applied in policy impact analysis and experimental analysis since its straightforward implementation (Khander et al. 2010); it aims at comparing changes over time of an intervention in a group that are affected or treated to a group that is not (or control group).

Additionally, the DiD is an attractive option when using research design based on controlling for confounding; it has the advantage of eliminating unobserved differences between treated and non-treated individuals that are time invariant and which cross-section matching estimators fail to eliminate (Smith and Todd 2005; Lechner 2011). Moreover, the matching procedure ensures that similar regions are compared as treatment and control group.

Under this before-after framework, there is a pre-treatment era and a post-treatment era; and between these two periods the policy intervention took place. A key assumption is the parallel trends between the treatment and control group: an average change in the comparison (or control) group represents the counterfactual change in the treatment group if there were no treatment. Although this assumption presents some difficulties to be tested, there are some alternatives. For instance, if it is possible to have data for more than one pre-treatment period, one can estimate average treatment effects for those periods. If they are statistically significant, then there is evidence against the pre-trend common assumption, in other words, in the pre-treatment era the effect was already present (Beatty and Shimshack 2011; Lima and Silveira-Neto 2015).

The propensity score matching is a non-experimental sampling method that produces a control group whose distribution of covariates is similar to that of the treated group (Khander et al. 2010). The idea is to find a similar control unit to compare with a treated unit, thus to reduce selection bias and improve the balance between treated and control group.

Here, we will perform the kernel matching[39], in which all treated units are matched with a weighted average of all controls and weights are inversely proportional to the distance between the propensity score of the treated and control groups. There are two main advantages of using this estimator (Baser 2006): first, since all controls are used in weighting, lower variance is achieved; second, it works better with large and asymmetrically distributed control data as it is in this case.

[39] Other common matching estimators are the nearest-neighbor and 2 to 1 matching, the radius matching, the stratified matching and the Mahalonobis matching.

In this case, data is available at the municipal level for two periods: 2000 (baseline or pre-CDM) and 2010 (follow-up or post-CDM). As the follow up period is 2010, we considered only those municipalities with CDM projects implemented before 2010 as treatment group. In addition, we have differentiated the projects according four types: hydro, biomass energy, landfill gas and methane avoidance. Wind projects were not included because most CDM investments in projects under this category took place after 2010. Municipalities with CDM projects by project type before 2010 are displayed in Table 4.

Table 4
Municipalities with CDM projects by project type
(Before 2010)

Region	Total municipalities with CDM Projects	Municipalities by project type			
		Hydro	Biomass Energy	Landfill Gas	Methane avoidance
North	7	4	1	1	1
North east	6	0	2	3	1
Central-west	41	16	2	1	23
South-east	97	13	26	16	42
South	53	21	8	3	20
Total	**168**	**54**	**39**	**24**	**87**

Source: Based on UNEP data

After finding good matches for the treatment group, average treatment effects are estimated. The Average Treatment Effect on the Treated (or ATET) is the difference between the outcomes of the treated and the outcomes of the treated if they had not been treated. Regarding treatment groups, the treated group is represented by those municipalities where CDM projects were implemented, while the control group is represented by non-CDM municipalities.

With respect to the covariates, a list is displayed in Table 5. The variables selected as covariates are used for matching. In the selection of these covariates, we consider aspects such as geography and weather (e.g. longitude, latitude, altitude), municipality size (area, population), economic conditions (employment in the industry sector, extreme poverty), infrastructure and accessibility (distance to

capital of the federate state). The rationale behind matching is to identify (based on the available covariates) a control municipality with similar characteristics of a treated municipality for comparisons.

Table 5
List of covariates

Variable	Unit	Source
Longitude	Decimal degrees	IPEA
Latitude	Decimal degrees	IPEA
Altitude	Decimal degrees	IPEA
Population	Number	IBGE
Ratio of rural population	%	IBGE
Area	km^2	IBGE
Distance to capital of the federate state	Km	IBGE
Percentage of population in domiciles with waste collection	%	IBGE
Percentage of population in domiciles with electricity power	%	IBGE
Percentage of population in domiciles with running water	%	IBGE
Illiteracy rate	%	IBGE
Infant mortality rate	%	IBGE
GDP's share in the industry sector	%	IBGE

The main data sources of the covariates are the Brazilian Institute of Geography and Statistics (IBGE), the Institute for Applied Economic Research (IPEA). Stata 14 was used for data analysis. Diagnostic tests for balancing of covariates for each project type are shown in the Appendix.

5. Results

Impacts were estimated for projects in the renewable energy (hydro and biomass energy projects), and waste handling and disposal (landfill gas and methane avoidance projects) sectors. Impacts of wind energy projects were not estimated due to sample size as most projects under this category were implemented after 2010. Results for the renewable energy projects sample are displayed in tables 6 and 7 (hydro and biomass energy, respectively).

Table 6
Estimations for CDM renewable energy projects
Project type: Hydro

Outcome variables	Baseline					Follow-up					DiD	
	Control	Treated	Diff	s.e.		Control	Treated	Diff	s.e.			
Overall MHDI	0.592	0.582	-0.01	0.002	**	0.705	0.706	0.001	0.002		0.011	***
Income MHDI	0.639	0.646	0.008	0.002	*	0.696	0.703	0.007	0.002	*	-0.001	
Overall FMDI	0.598	0.590	-0.008	0.003	**	0.703	0.705	0.002	0.012		0.010	**
Labour and income FMDI	0.418	0.446	0.028	0.006	*	0.460	0.479	0.019	0.006	*	-0.009	
Per capita income	459.6	482.63	23.01	7.09	**	647.4	663.7	16.2	7.79	**	-6.7	
% of poor households	25.06	26.79	1.72	0.53	**	11.49	11.62	0.12	0.53	**	-1.60	**
% of people vulnerable to poverty	49.4	50.0	0.62	0.66		28.4	29.3	0.84	0.66		0.22	
Theil index	0.50	0.56	0.06	0.006	**	0.40	0.44	0.04	0.006	**	-0.02	**
Unemployment rate	8.91	8.68	-0.23	0.16		4.92	5.15	0.23	0.16		0.45	

(*) Significant at 10%; (**) Significant at 5%, (***) Significant at 1%

Results of the hydro project sample show that the overall FMDI in the treatment (or CDM) after intervention had a very slight and significant increase of 0.011 points. Similarly, the overall MHDI also shows an increase of 0.01 after intervention in those municipalities with CDM projects. There are no significant impacts on labor/income indexes probably due to labor demand characteristics: hydro projects are capital intensive and might generate only few job opportunities, mostly for skilled workers during construction and operation phases (Helston and Farris 2016); therefore, a significant local employment generation is not expected.

Regarding poverty indicators, although the percentage of poor households are higher in the treatment than in the control group in the baseline, this difference decreases after the intervention by 1.6 percentage points in municipalities with CDM. Moreover, the Theil index also reported slightly but significant differences: inequality dropped by 0.02 percentage points in CDM municipalities. Hydro projects in other countries have been successful in reducing poverty through improvements in energy security at the local level (IHA 2002, 2017). Enhanced energy security has the potential to improve time allocation and economic productivity at the household level that could lead to increased

income opportunities with positive effects in poverty reduction (Bonan et al. 2016). Despite this impact on local poverty reduction, no significant impacts have been found on unemployment rates.

Table 7
Estimations for CDM renewable energy projects
Project type: Biomass energy

Outcome variables	Baseline					Follow-up					DiD	
	Control	Treated	Diff	s.e.		Control	Treated	Diff	s.e.			
Overall MHDI	0.64	0.64	0.00	0.003		0.73	0.73	0.00	0.003		0.00	
Income MHDI	0.67	0.67	0.00	0.002		0.72	0.72	0.00	0.002		0.00	
Overall FMDI	0.66	0.66	0.00	0.004		0.76	0.77	0.02	0.004	**	0.02	**
Labour and income FMDI	0.47	0.46	-0.02	0.008	**	0.54	0.59	0.05	0.008	**	0.07	**
Per capita income	550.3	547.2	-3.1	9.51		744.3	733.7	-10.6	9.51		-7.5	
% of poor households	16.1	15.6	-0.4	0.4		15.6	15.7	0.1	0.4		0.5	
% of people vulnerable to poverty	40.1	39.0	-1.0	0.65		19.6	20.8	1.2	0.65	*	2.2	**
Theil index	0.48	0.46	-0.02	0.006	***	0.37	0.39	0.02	0.006	**	0.04	**
Unemployment rate	11.2	12.3	1.1	0.19	*	5.6	6.8	1.2	0.19	*	0.45	

(*) Significant at 10%; (**) Significant at 5%, (***) Significant at 1%

In the case of biomass energy projects (table 7), there is a positive and significant difference only on the overall FMDI of 0.02 point, indicating an improvement in this general development index in municipalities with CDM projects. However, this is not the case for the overall MHDI[40]. Moreover, there is a positive and highly significant increase on the labor and income FMDI of 0.07 point, indicating that CDM has positively contributed to activate the local economy.

Biomass energy projects can generate both unskilled and skilled job positions during a project's life[41] (IIED 2010; ERIA 2008); indeed they may have the potential to perpetuate employment at the local/regional level (BERC 2006). Moreover, biomass production is a labor intensive process that could represent an important source of primary jobs in rural areas (ERIA 2008). In addition, provision

[40] One possible explanation for this difference is that, despite similarities, the FMDI covers some dimensions in a more detailed way (e.g. the employment/income sub-index is estimated using several labor and income indicators) than the MHDI (for the income sub-index, it is only used the average capacity of procuring goods and services by the inhabitants of a municipality).

[41] Employment generation may take place during construction, operation, collection, biomass processing, transportation of biomass material and working at the bioenergy conversion plant (ERIA 2008).

of quality power (cleaner and more reliable energy supply) might help in increasing enterprise development, contributing to increase and diversify income sources at the local level (IIED 2010). But despite these anticipated effects, no significant impacts have been found on poverty indicators and unemployment rate.

Tables 8 and 9 display the results for waste management projects (landfill gas and methane avoidance projects, respectively). In the case of landfill gas projects, there is a positive and highly significant increase on the overall FMDI of 0.02 points in CDM municipalities (table 8). In addition to that, the labor and income FMDI shows an increase of 0.04 points in the treatment group after intervention. Landfill gas projects have the potential to generate employment opportunities for semi-skilled and high-skilled workers along the different phases of the project[42] (Bacon and Kojima 2012). In addition, businesses might benefit from the cost savings associated with using landfill gas as a replacement for more expensive fossil fuel, thus improving income at the local level (EPA 2017). No impacts on poverty indicators were found. Impact on inequality is significant and negative, while there is a significant reduction on unemployment rates.

In the case of methane avoidance projects, there is a positive and significant increase on the overall FMDI of 0.02 points in CDM municipalities (table 9). Additionally, the labor and income FMDI also shows an increase of 0.06 points in the treatment group after intervention. Results on poverty indicators do show a negative effect, but significant at 10% meaning that CDM projects have not contributed to reduce poverty at the municipal level. Regarding unemployment rates, the impact is significant and indicates a reduction in treated municipalities.

[42] For instance, during design, construction, operation and maintenance of equipment at the landfill and power generation unis.

Table 8
Estimations for CDM Waste management and disposal projects
Project type: Landfill gas

Outcome variables	Baseline					Follow-up					DiD	
	Control	Treated	Diff	s.e.		Control	Treated	Diff	s.e.			
Overall MHDI	0.66	0.67	0.01	0.004	*	0.75	0.762	0.01	0.004	*	0.001	
Income MHDI	0.70	0.71	0.009	0.004	*	0.75	0.76	0.01	0.004	*	0.005	
Overall FMDI	0.67	0.70	0.003	0.006	***	0.78	0.82	0.04	0.006	**	0.02	**
Labour and income FMDI	0.53	0.62	0.09	0.01	***	0.65	0.77	0.12	0.01	**	0.04	***
Per capita income	665.6	712.5	46.9	19.7	*	862.7	930.7	68.0	19.7	*	21.10	
% of poor households	14.0	13.4	-0.6	0.49		5.9	5.7	-0.3	0.49		0.30	
% of people vulnerable to poverty	34.8	32.2	-2.6	0.84	***	19.2	18.4	-0.8	0.84		1.82	
Theil index	0.51	0.50	-0.01	0.009		0.43	0.47	0.04	0.009	**	0.05	***
Unemployment rate	12.9	15.8	2.88	0.27	***	6.6	7.1	0.5	0.27	*	-2.39	***

(*) Significant at 10%; (**) Significant at 5%, (***) Significant at 1%

Table 9
Estimations for CDM Waste management and disposal projects
Project type: Methane avoidance

Outcome variables	Baseline					Follow-up					DiD	
	Control	Treated	Diff	s.e.		Control	Treated	Diff	s.e.			
Overall MHDI	0.605	0.624	0.019	0.002	**	0.715	0.72	0.014	0.002	**	-0.005	
Income MHDI	0.65	0.67	0.02	0.002	**	0.70	0.72	0.02	0.002	**	0.00	
Overall FMDI	0.61	0.63	0.02	0.003	***	0.71	0.75	0.04	0.003	***	0.02	***
Labour and income FMDI	0.43	0.45	0.02	0.006	***	0.488	0.57	0.08	0.006	***	0.06	***
Per capita income	500.1	554.1	54.0	7.7	*	685.2	753	67.9	8.65	*	13.9	
% of poor households	22.7	19.5	-3.2	0.41	***	9.7	7.6	-2.1	0.41	***	1.1	*
% of people vulnerable to poverty	47.0	43.8	-3.2	0.55	*	26.4	23.1	-3.3	0.55	*	-0.14	
Theil index	0.52	0.55	0.03	0.005	**	0.41	0.43	0.02	0.005	**	-0.01	*
Unemployment rate	9.4	9.6	0.2	0.14		5.1	4.9	-0.2	0.14	*	-0.4	**

(*) Significant at 10%; (**) Significant at 5%, (***) Significant at 1%

6. Discussion and conclusions

In contrast to most previous studies in this field which are ex-ante analysis based on data provided by project developers, this research has attempted to estimate ex-post impacts of CDM projects on sustainable development using empirical data from official statistical sources. Here, we focus on identifying impacts on development and poverty indicators. Results show that there are positive and significant differences for the income and labor FMDI; small and significant effect shows that CDM projects have the potential to stimulate the local economy through employment and income benefits. This result was found for all project types, except for hydro. This might be explained through the differences in factor's demand requirements by project's category: hydro projects tend to be more capital intensive, while the other project categories (e.g. biomass energy) are more labor intensive.

Positive and significant differences have also been identified for the overall FMDI in those municipalities with CDM projects. For interpretation, it is important to take into account that this indicator is a compound index that weights three different dimensions: employment/income, health and education. Although impacts on health are expected (e.g.: due to the reduction of air pollution by landfill gas and methane avoidance projects), the estimation of this component does not include direct measurements on improvements, for example, in the case of respiratory diseases. Moreover, the educational dimension CDM investments are not expected to have a significant effect on the educational aspect; therefore, this finding might be interpreted carefully[43].

Other aspects or dimensions such as environmental quality, which are also relevant when analyzing local sustainable development, were not assessed in this paper due to data constrains. Projects such as landfill gas and methane avoidance are expected to achieve considerable reductions in several air pollutants and volatile organic compounds (VOCs) emissions, thus leading to significant improvements in health conditions at the local level (EPA 2017). Another important expected benefit of these projects is its high potential to reduce groundwater pollution, which might have a significant impact on local health and environment (EPA 2012).

[43] Despite the similarities between the MHDI and the FMDI, only the last index has shown significant differences in the analysis. This can be attributed to the differences in data sources, dimensions included and methodologies for calculating each of them.

No long-term impacts on poverty and inequality indicators have been identified, except for hydro projects. These findings are in line with ex-ante studies based on the PDDs that question the contribution of CDM projects to poverty alleviation (Sirohi 2007; Subbarao and Lloyd 2011; Crowe 2013). Presumably, some short-term effects could have taken place during the first two or three years after project's registration (e.g.: during construction and/ or operation phases), resulting in positive changes but these could have vanished after few years. The decade that separates the pre-treatment and the post-treatment period (2000 and 2010, respectively) prevents us to validate this hypothesis of short-term effects of CDM investments on poverty at the municipal level. However, for policy purposes, it is also relevant to know the long term or more permanent response of the CDM implementation. Indeed, more longitudinal research is needed that looks into the development of effects over time, covering both temporary and permanent effects.

Regarding the ability of the selected indicators to capture the CDM effects, it can be argued that some indicators represent more accurately the reality of the Brazilian municipalities than others; therefore, they could capture the CDM impacts more precisely. This is the case when comparing the income and labour FMDI with the income MHDI. As described in the data subsection, while the income MHDI represents per capita income, the income and labour FMDI is an average of several indicators that represent aspects such as labour market, income creation and income inequality. Thus, this last indicator may reflect better the economic performance at the municipal level. Another important difference is data sources, which may play a role in the accuracy of these indicators: while all MHDI indicators are built on census data, the FMDI indicators use official statistics from the Ministry of Labour.

With respect to the ability of other selected indicators such as poverty variables and the Theil index, it can be argued that effects on poverty alleviation and inequality could be even more long-term as it may take a while until employment generation could lead to better living standards at the local level. For this reason, the time frame of this analysis may not fit to identify effects in these indicators. Regarding unemployment rates, as this variable captures only the formal labor market, it may not be a suitable indicator if the CDM attracts workers from the informal labor market. As quantification is

relevant for assessment, further research may focus on the development of indicators able to capture the CDM impacts more accurately.

It is important to highlight that the implementation of any renewable energy project will not lead automatically to sustainable development benefits[44]. Although enhanced energy access has demonstrated to provide communities with several benefits, e.g. time allocation improvements and more dynamic labor markets (Bonan et al. 2016), findings are still inconclusive due to methodological challenges to elucidate causal-link effects (Alloisio et al. 2017). The causality chain may involve high levels of complexity due to the diverse interactions among socio-economic variables and sectors; moreover, potential negative effects might threaten to offset positive gains on welfare (ERIA 2007).

Although some project types might be labor intensive (e.g. biomass energy) and thus might contribute to increase local employment, they might be also input intensive (e.g. land, water, crops). A resource re-allocation would take place in favor of the project and it might affect input availability as well as agricultural prices (e.g. food prices), in which case the benefit drawn from employment is offset by the detrimental effects of suboptimal resource exploitation. This would explain why our findings do not show similar impacts on employment, income and poverty indicators for all project categories. It is therefore essential to have a holistic view of all potential impacts before implementing any clean energy or environmental-friendly project to understand how benefits are distributed and how a CDM project can really contribute to sustainable development at the local/regional level.

The limited contribution of CDM projects in reducing poverty, in particular in the long-term, is also in line with the debate that highlights the need of reforming this instrument (Olsen and Fenhann 2008; Shishlov and Bellassen 2012; Michaelowa et al. 2014; Dirix et al. 2016). Some of the most common weaknesses discussed are, for instance, the lack of incentives to achieve the sustainable development target (that might lead to the infamous trade-off between CDM objectives), the absolute absence of monitoring and verification of achievement, the lack of a standard definition and measurements for sustainable development and the lack of a theoretical framework that explains the attribution of different project types on local sustainable development. Future research may attempt to deeper

[44] Although most literature are focused on detangling the causality effects of renewable energy projects on sustainable development, this can be extended to other categories such as waste management projects.

disentangle the contribution of renewable energy projects to sustainable development in order to enhance our understanding on the causality chain and their potential effects.

Some alternatives have been discussed in order to enhance the performance of CDM projects in delivering sustainable development benefits such as the adoption of premium add-on standards (Wood 2011; Crowe 2013), the adoption of discount rates to CERs (Alexeev et al. 2010) or the implementation of a two-track CDM (Torvanger et al. 2013). The implementation of these proposals, however, is not exempt of political and market challenges. Other important challenges still remain such as the adequate quantification tools of project's performance with respect to sustainable development achievements, and monitoring and reporting of the impacts (Olsen et al. 2017). Lessons from the CDM experience could contribute in the formulation of new instruments in the context of the Paris Agreement. This experience is valuable for the future design, formulation and implementation of the Sustainable Development Mechanism (SDM) established under the Accord, which keeps the twofold objective of the CDM.

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Appendix: Diagnostic tests

After performing the matching and estimating the treatment effects, it is required to conduct a diagnostic analysis to assess the extent of corresponding balancing achieved on the two matched samples (treated and control) before and after matching. This procedure is also used to choose the set of matching parameters (covariates) that achieves the best balancing. There are several options to test for it; here, we use some numeral and graphical diagnostics: the standardized percentage bias, ratios of variance and some graphical representation using the estimated propensity scores. If several tests indicate balance, there is a greater likelihood that covariates are balanced across treatment and control groups in the matched sample.

The first indicator or the standardized percentage bias is the percentage difference of the sample means in the treated and control sub-samples as a percentage of the square root of the average of the sample variances in the treated and control group (Rosenbaum and Rubin 1985). The percentage bias should be under 10 to be considered acceptable. The second measure, the variance ratio, is the ratio between the variance of the treated over the variance of the control group. If the Rubin's variance ratio is applied, it is the ratio of the variance of the residuals orthogonal to the linear index of the propensity score in the treated group over the control group (Rubin 2001). This indicator, again, is estimated for each covariate used; values between 0.8 and 1.25 represent a "good" balance.

The last measure is a graphical representation or a density plot of the covariates in treated against density plot of covariates in control before and after the matching. Graphical diagnostics can be helpful for a quick assessment of the extent of covariate imbalance. Both indicators for each covariate (standardized percentage bias and variance ratio) are displayed together with overall measures of covariate imbalance for the four project's types.

Table 1.1: Standardized percentage bias and ratio of variance before and after matching

(Type: Hydro)

Covariate	Unmatched Matched	Mean Treated	Mean Control	% Bias	% reduct bias	V(T)/ V(C)
Longitude	U	50.25	46.07	73.2		0.60
	M	50.46	49.47	17.5	76.2	1.18
Latitude	U	-20.59	-16.32	-59.2		0.51
	M	-20.59	-20.34	-3.4	94.2	0.76
Altitude	U	470.52	385.76	32.7		0.72
	M	464.85	452.28	4.8	85.2	0.80
Population	U	72392	31301	18.2		1.80
	M	35544	41889	-2.8	84.6	0.5
Ratio of rural population	U	0.24	0.39	-67.7		0.85
	M	0.23	0.26	-13.4	80.2	0.92
Area	U	1919.7	1530.3	8.6		0.25
	M	1995.4	1893.6	2.2	73.9	0.26
Distance to capital of the federate state	U	947.2	1077.8	-31.0		0.80
	M	945.8	943.5	-0.6	98.2	0.84
Access to waste collection at home	U	95.87	87.43	58.5		0.12
	M	95.94	94.96	6.8	88.4	0.54
Access to running water at home	U	89.45	75.96	66.2		0.33
	M	89.46	88.59	4.2	93.6	0.84
Illiteracy rate	U	10.14	19.09	-99.9		0.20
	M	10.26	11.13	-9.7	90.3	0.62
Infant mortality rate	U	18.32	26.38	-79.3		0.19
	M	18.26	18.94	-6.7	91.6	0.68
GDP share in the industry sector	U	0.23	0.15	60.6		1.27
	M	0.23	0.20	18.2	70.0	0.71
Region	U	3.93	3.23	64.4		0.36
	M	3.92	3.87	5.1	92.0	0.62

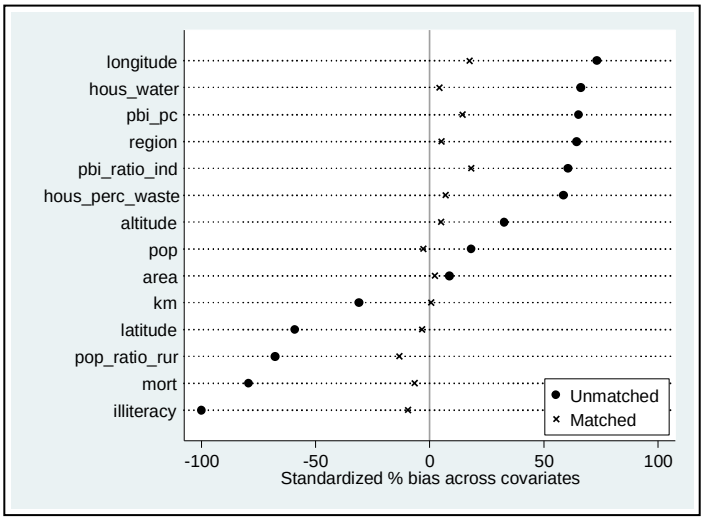
Table 1.2: Overall measures of covariate imbalance

(Type: Hydro)

Sample	Ps R^2	LR chi2	p>chi2	Mean Bias	Med Bias	Rubin B	Rubin R
Unmatched	0.131	230.20	0.00	56.1	62.5	128.8	0.26
Matched	0.030	14.14	0.44	7.8	5.9	29.8	0.57

Graph 1.1: Standardized percentage bias before and after matching

(Type: Hydro)



Note: Unmatched (bias before matching); matched (bias after matching).

Graph 1.2: Density plots of the propensity score

(Typo: Hydro)

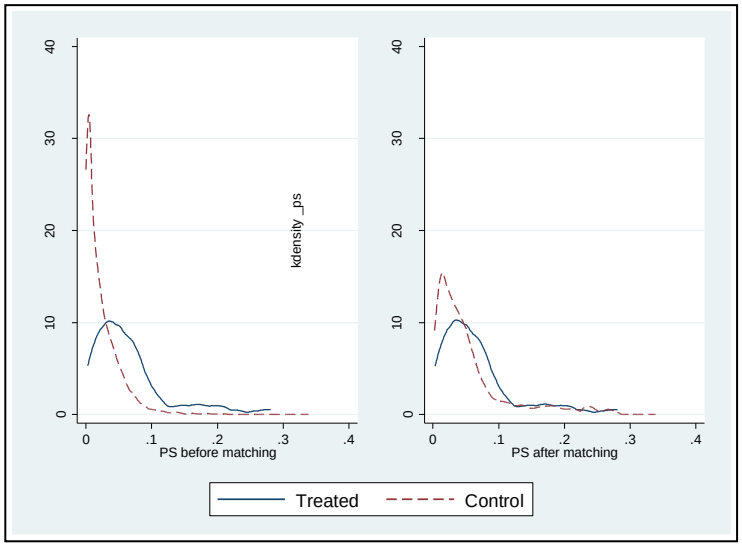


Table 2.1: Standardized percentage bias and ratio of variance before and after matching

(Type: Biomass energy)

Covariate	Unmatched Matched	Mean Treated	Mean Control	% Bias	% reduct bias	V(T)/ V(C)
Longitude	U	48.77	46.12	47.7		0.51
	M	49.17	49.04	2.5	94.9	1.45
Latitude	U	-20.81	-16.36	-64.2		0.39
	M	-21.68	-21.85	2.5	96.1	0.80
Altitude	U	458.34	386.64	26.9		0.82
	M	493.07	501.2	3.0	88.7	0.56
Population	U	1.1e+05	31448	25.5		3.63
	M	52746	56088	-1.2	95.5	0.05
Ratio of rural population	U	0.14	0.39	-130.0		0.45
	M	0.08	0.11	-16.1	87.6	1.06
Area	U	1154.6	1539.4	-9.1		0.10
	M	1011.8	1077.8	-1.6	82.9	0.08
Distance to capital of the federate state	U	839.8	1077.3	72.5		0.05
	M	752.6	768.0	0.0	99.9	0.89
Access to waste collection at home	U	97.54	87.49	72.5		0.05
	M	98.55	98.54	0.0	99.9	0.89
Access to running water at home	U	93.28	76.05	89.1		0.20
	M	96.11	95.60	2.6	97.1	0.98
Illiteracy rate	U	9.99	76.05	89.1		0.20
	M	8.94	95.6	2.6	97.1	0.98
Infant mortality rate	U	19.09	26.30	-66.7		0.36
	M	17.32	17.34	-0.1	99.8	0.83
GDP share in the industry sector	U	0.29	0.15	121.8		0.86
	M	0.31	0.29	16.7	86.3	0.42
Region	U	3.97	3.23	66.6		0.40
	M	4.06	4.09	-2.6	96.2	0.64

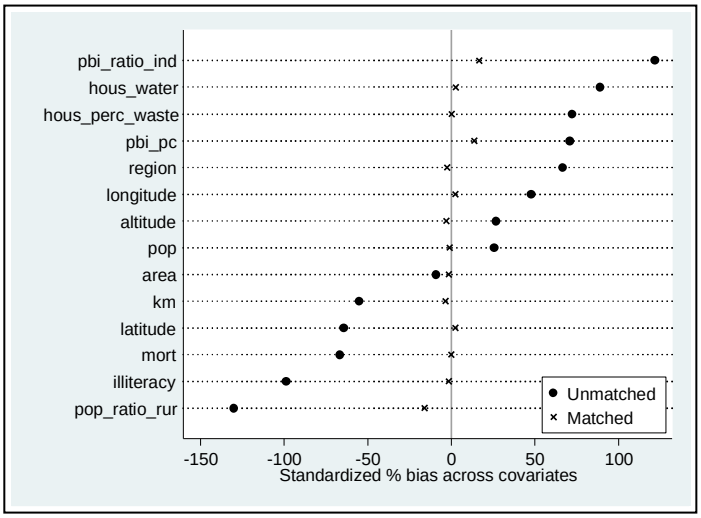
Table 2.2: Overall measures of covariate imbalance

(Type: Biomass energy)

Sample	Ps R^2	LR chi2	p>chi2	Mean Bias	Med Bias	Rubin B	Rubin R
Unmatched	0.188	169.28	0.00	67.5	66.6	160.6	0.29
Matched	0.031	5.12	0.98	4.8	2.5	40.6	0.61

Graph 2.1: Standardized percentage bias before and after matching

(Type: Biomass energy)



Note: Unmatched (bias before matching); matched (bias after matching).

Graph 2.2: Density plots of the propensity score

(Type: Biomass energy)

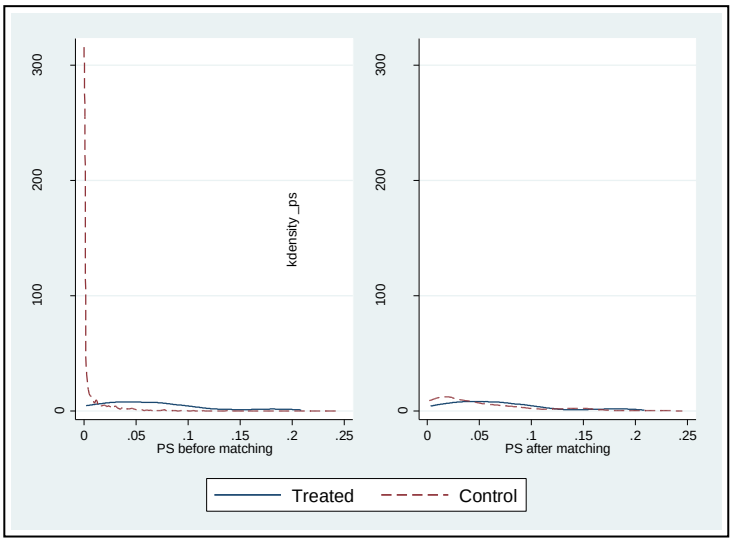


Table 3.1: Standardized percentage bias and ratio of variance before and after matching

(Type: Landfill gas)

Covariate	Unmatched Matched	Mean Treated	Mean Control	% Bias	% reduct bias	V(T)/ V(C)
Longitude	U	45.77	46.15	-6.9		0.49
	M	47.28	47.92	-11.5	-68.4	0.78
Latitude	U	-21.11	-16.37	-64.0		0.60
	M	-23.59	-22.40	-16.1	74.8	0.70
Altitude	U	426.62	533.71	-11.4		0.96
	M	383.46	387.17	1.2	89.0	1.41
Population	U	8.8e+05	28276	55.4		340.9
	M	2.6e+05	2.3e+05	1.5	97.2	0.84
Ratio of rural population	U	0.05	0.39	-203.0		0.07
	M	0.07	0.08	-7.6	96.2	0.51
Distance to capital of the federate state	U	1021.6	1075.9	-14.5		0.42
	M	1014.7	930.5	-22.4	-54.9	0.49
Access to electricity at home	U	99.64	91.86	79.4		0.00*
	M	99.51	99.55	-0.4	99.5	0.77*
Access to running water at home	U	95.92	76.09	110.4		0.04*
	M	95.65	95.6	0.3	99.7	0.79
Illiteracy rate	U	6.39	19.0	-149.9		0.06
	M	6.47	6.93	-5.5	96.3	0.78
Infant mortality rate	U	17.80	26.29	-81.7		0.24
	M	16.76	17.23	-4.6	94.4	0.81
GDP share in the industry sector	U	0.25	0.15	92.2		0.54
	M	0.26	0.28	-10.2	88.9	0.41
Region	U	3.7	3.2	40.0		0.56
	M	4	3.8	9.5	76.2	0.87

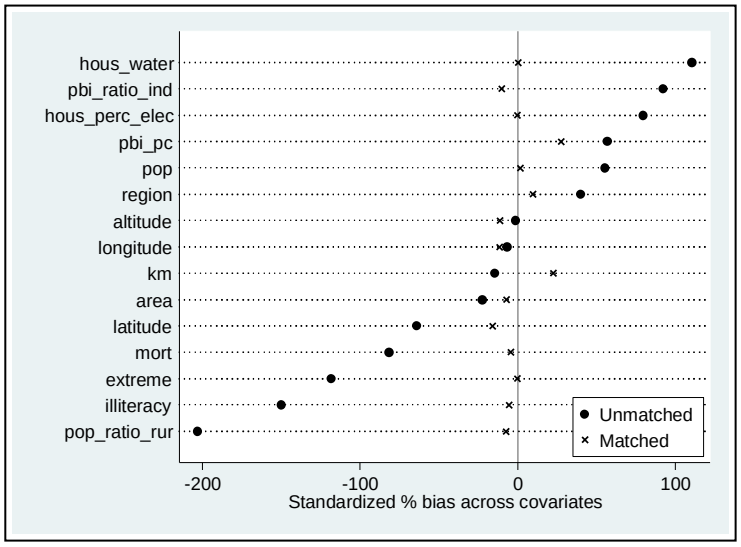
Table 3.2: Overall measures of covariate imbalance

(Type: Landfill gas)

Sample	Ps R^2	LR chi2	p>chi2	Mean Bias	Med Bias	Rubin B	Rubin R
Unmatched	0.43	225.92	0.00	73.1	64.0	130.0	2.14
Matched	0.01	10.14	0.81	9.1	7.6	27.7	0.8

Graph 3.1: Standardized percentage bias before and after matching

(Type: Landfill gas)



Note: Unmatched (bias before matching); matched (bias after matching).

Graph 3.2: Density plots of the propensity score

(Type: Landfill gas)

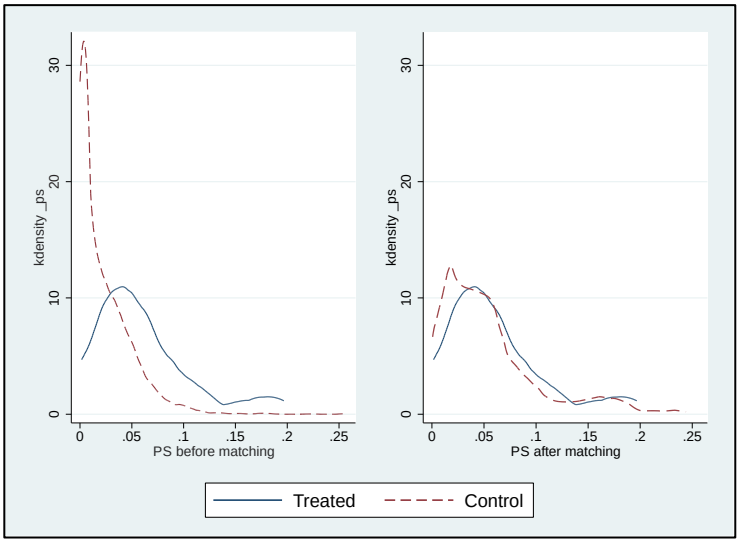


Table 4.1: Standardized percentage bias and ratio of variance before and after matching

(Type: Methane avoidance)

Covariate	Unmatched Matched	Mean Treated	Mean Control	% Bias	% reduct bias	V(T)/ V(C)
Longitude	U	49.23	46.09	58.4		0.42
	M	49.60	49.04	10.3	82.4	1.12
Latitude	U	-21.55	-16.29	-78.2		0.31
	M	-21.56	-21.70	2.2	97.2	0.80
Altitude	U	548.37	384.19	62.5		0.77
	M	551.77	533.71	6.9	89.0	0.80
Population	U	22392	28301	27.8		1.13
	M	15544	17889	2.2	92.2	1.09
Ratio of rural population	U	0.19	0.39	-102.9		0.55
	M	0.19	0.23	-21.3	79.3	0.61
Area	U	1757	1532.7	5.1		0.18
	M	1858.5	1661	4.5	12.0	0.13
Distance to capital of the federate state	U	877.88	1079.3	-50.0		0.57
	M	877.35	884.9	-1.9	96.2	0.80
Access to electricity at home	U	98.36	91.78	64.3		0.08
	M	98.27	91.63	6.3	90.2	0.44
Access to running water at home	U	93.81	75.86	97.2		0.33
	M	93.66	91.86	9.8	90.0	0.08
Illiteracy rate	U	8.38	9.09	-123.9		0.13
	M	8.44	9.50	-12.3	90.1	0.69
Infant mortality rate	U	17.80	26.38	-85.4		0.17
	M	17.62	18.28	-6.6	92.3	0.80
GDP share in the industry sector	U	0.20	0.15	47.6		0.79
	M	0.20	0.19	8.2	83.1	0.66
Region	U	3.93	3.23	61.6		0.33
	M	3.92	3.95	-3.7	93.9	0.82

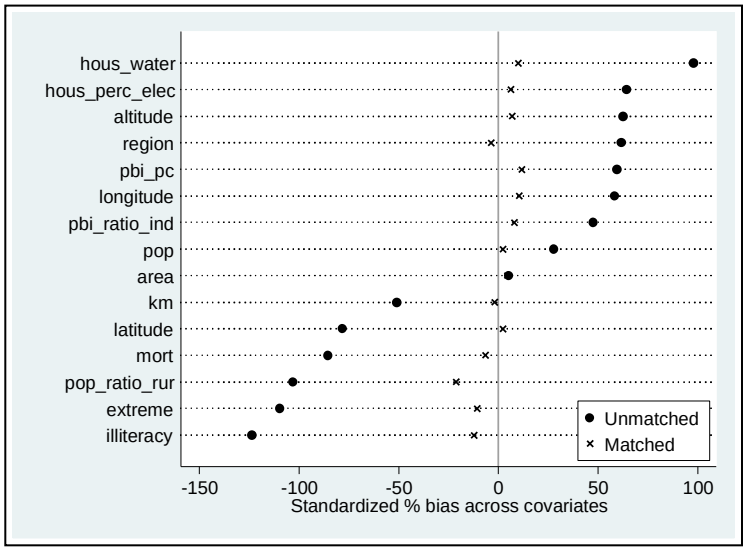
Table 4.2: Overall measures of covariate imbalance

(Type: Methane avoidance)

Sample	Ps R^2	LR chi2	p>chi2	Mean Bias	Med Bias	Rubin B	Rubin R
Unmatched	0.211	399.22	0.00	69.0	62.5	104.8	2.14
Matched	0.025	12.47	0.64	7.9	6.9	27.3	0.72

Graph 4.1: Standardized percentage bias before and after matching

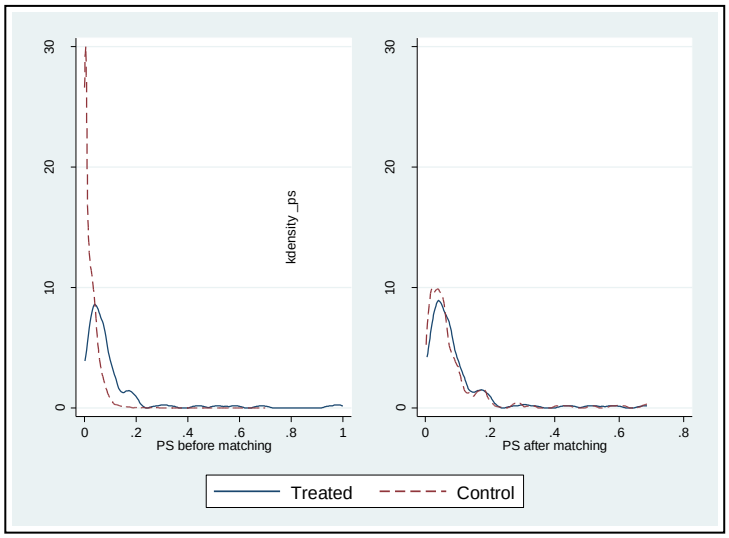
(Type: Methane avoidance)



Note: Unmatched (bias before matching); matched (bias after matching).

Graph 4.2: Density plots of the propensity score

(Type: Methane avoidance)



4.3. Paper 2

Mori-Clement, Y. and B. Bednar-Friedl (2018): Do Clean Development Mechanism projects generate local employment? Testing for sectoral effects across Brazilian municipalities. *Ecological Economics* (resubmitted after minor revisions)

Do Clean Development Mechanism projects generate local employment? Testing for sectoral effects across Brazilian municipalities

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Abstract

Clean Development Mechanism (CDM) projects have a two-fold objective: reducing greenhouse gas emissions and contributing to sustainable development. But while the contribution to mitigation has been analyzed extensively in the literature, the impact on development has seldom been quantified empirically. This paper addresses this gap by investigating the impacts of CDM projects on local employment. We use a dynamic panel regression model across Brazilian municipalities for the period 2004-2014 to estimate cross-sectoral employment effects of two project types: hydro projects and methane avoidance projects. We find that CDM projects have mixed effects on sectoral employment. Municipalities with hydro projects show a positive impact on commerce and a negative on agricultural employment. In a similar way, these effects have also been identified in municipalities with methane avoidance projects, as well as positive effects in the service and the construction sector. Regardless of project type, the sectoral employment effects are found to be small and transitory, i.e. these took place immediately or within the first, second or third year after the registration of the project, corresponding to the construction phase and early years of operation. Revenues from Certified Emission Reductions (CER) seem to have no or a very small positive impact on sectoral employment, and no significant impact is found for the CER price fall in 2012.

Keywords: Employment generation; renewable energy; hydro and methane avoidance projects; clean development mechanism; CER crisis; dynamic panel model

1. Introduction

In order to ensure that global climate average does not exceed the 2°C target, mitigation measures must be taken to achieve the necessary reduction in emissions to cope with climate change by both industrialized and developing countries. With the Paris Agreement (2015), mitigation efforts are required from both industrialized and developing countries, and industrialized countries are to assist developing countries in their efforts via international climate finance and technology exchange. To understand the impacts of projects funded by such climate finance, this paper draws on experience from the Clean Development Mechanism (CDM), which is the primary instrument to support mitigation efforts in developing countries within the Kyoto Protocol.

The CDM has a dual objective of helping developed countries fulfill their commitments to reduce greenhouse gas emissions as well as to aid developing countries in achieving sustainable development (CDM-Article 12). Employment generation is recognized as one of the most crucial approaches to attaining sustainable development; that is why, its key role has been featured by the eighth Sustainable Development Goal, which aims at "*promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*" (UN 2015). Job creation is one of the benefits most commonly claimed by different types of CDM projects (UNFCCC 2012; Spalding-Fecher et al. 2012) since these investments are expected to bring a significant stimulus to the local economy along project's life (Olhoff et al. 2004).

Although CDM projects have this two-fold goal, only the emission reductions objective is linked to pricing mechanisms, which incorporates economic incentives to encourage fulfillment of this objective (Sutter 2003). While CO_2 emission reductions are verified by the UNFCCC and generate revenues to project developers in the form of Certified Emission Reductions[45] (CERs), contributions to local sustainable development lacks monitoring of accomplishment or such a monetary incentive.

The objective of this paper is therefore to contribute to understand the impacts of CDM projects on development. In particular, we focus on assessing effects on cross-sectoral employment at the municipal level in Brazil, which is the third largest country worldwide regarding registered CDM

[45] A CER is equal to 1 tonne of CO_2 equivalent (1 tCO_2e).

projects and hosted the first project worldwide in 2004[46]. With nearly 350 CDM projects implemented over a decade, Brazil constitutes an interesting case study to evaluate impacts over time.

At the sectoral level, in developing countries like Brazil, the CDM projects typically target the renewable energy sector (e.g. hydro, wind, biomass energy) and the waste handling and disposal sector (e.g. methane avoidance and landfill gas) (UNEP 2015). Although all these project types are capable of reducing greenhouse gas emissions and thereby generating CERs, the potential effects for employment generation may differ considerably among types (Wang et al. 2013). In this paper, we focus on these two largest categories of CDM projects in Brazil: hydro in the category of renewable energy projects and methane avoidance in the category of waste handling and disposal projects.

Renewable energy projects tend to be more labor intensive than conventional energy sources (Altener 2003; Ecotec 2003), so they could potentially stimulate local employment in construction, operation and maintenance phases. Moreover, these projects could also induce employment benefits (or indirect employment) in other sectors such as agricultural and/or industrial through indirect demand of goods and services (del Rio and Burguillo 2008; Brown et al. 2012). But in addition to these positive effects on employment, other effects may be triggered by renewable energy projects. These projects might have the potential not only to induce expansive but also to induce contractive effects on employment, affecting energy-intensive sectors such as manufacturing (Hillebrand et al. 2006; Aldy et al. 2011). The net result on local employment will depend on how much the contractive effect offsets the positive impact at the local level.

Waste handling and disposal projects are labor intensive, but previous studies have found a comparatively smaller potential for employment generation (Subbarao and Lloyd 2011). The main difference to renewable energy projects is however that the required skill level e.g. in waste sorting is lower and therefore unskilled workers, who previously worked in other sectors like agriculture, can be employed and trained on the job.

This paper therefore attempts to address two important research gaps. Several papers have tried to investigate the achievements of CDM projects on employment generation inside and outside the

[46] The first CDM project registered in the pipeline was a landfill project in the municipality of Nova Iguaçu, in the federate state of Rio de Janeiro.

renewable energy sector. However, there are very few studies in the literature that have explored the economic impacts of waste handling and disposal projects at the local level. In this paper, first, we therefore address this research gap by providing empirical evidence on employment effects triggered by methane avoidance projects and we compare them to the effects generated by renewable energy projects.

Second, most of the empirical studies which investigate employment effects generated by CDM projects are ex-ante analyses based on information provided by the Project Design Document (PDD) of the CDM project (Lema and Lema 2013; He et al. 2014), which is basically data on project's expected or potential impacts at the local level, and thus it does not reflect what effectively occurred after project's implementation. Nussbaumer (2009) argues that the information provided by the PDDs is accurate and relatively reliable since it represents official documents that are evaluated by the Designated National Authorities (DNAs) before approval and registration of any CDM project in host countries; however, CDM project developers might have incentives to overstate potential achievements in local sustainable development (IOB 2007) since the fulfillment of this goal is one requirement to obtain validation and registration from the corresponding DNA. In this paper, we focus therefore on estimating effects on cross-sectoral employment by using empirical data that does not draw on the PDD but uses municipal employment data provided by statistical offices.

This paper is structured as follows: section 2 presents the literature review on impacts of CDM on employment generation in the manufacturing sector, while section 3 characterizes the CDM project portfolio in Brazil. Following that section 4 illustrates the methodological approach and data, while results from the regression analysis are shown in section 5. Finally, discussion and some conclusions are made in section 6.

2. Literature review

As a pre-requisite for validation and final registration in the pipeline, all CDM projects should deliver sustainable development benefits in the PDD. One of the most prominent and probably best claimed effects is the positive impact of renewable energy projects on local employment due to their

labor intensive features of renewable energy technologies that notably contrast with conventional energy sources (Ecotec 2002).

While the PDDs do not delineate the causal mechanisms how different types of CDM projects lead to employment generation, there is extensive literature on employment effects in the context of renewable energy projects. Although employment generation is claimed as one of the benefits of promoting renewable energy, it is not straightforward how the causality works. Behind the overall or net employment impact of implementing a renewable energy project, there are direct, indirect and induced effects to be taken into account (IRENA 2013). The direct effect describes the direct impact on employment of a project (e.g. construction of a plant); the indirect effect refers to employment generation that takes places in other sectors (e.g. jobs generated in the manufacturing sector – turbines for wind farms), while the induced effect refers to those jobs created due to spending that comes from household's earnings from working in the project. Since the overall impact depends on the direction and size of each effect, it is not possible to determine the net impact on employment *a priori*. While the net or overall employment effect is the sum of the three effects already discussed, the gross employment only considers the positive effects ignoring any possible negative impact (Meyer and Wolfgang 2014).

In the context of CDM projects, the most visible and direct effects on employment are generated during the construction phase (Altener 2003; May and Nilsen 2015) and also during operation and maintenance activities which requires fewer but highly skilled workers (Ecotec 2002; del Rio and Burguillo 2008; Brown et al. 2012). CDM projects may also generate indirect employment in the context of cross-sectoral employment benefits in sectors such as agriculture, industry, services or construction as well as induced employment through the creation of indirect demand of goods and services (Hillebrand et al. 2006; del Rio and Burguillo 2008; Brown et al. 2012).

For example, in the case of biomass energy technology, the agricultural sector can gain from the biomass production through planting and harvesting as well as from the switch from traditional to high profit crops for biomass industry (Altener 2003; El Bassam and Maegaard 2004). In wind energy, manufacturing can benefit from fabrication and/or assembly of components, while the

construction sector could profit from the construction and installation of wind farms (Ecotec 2003; Komor and Bazilian 2005).

But in addition to these positive effects, also other employment effects may be triggered by renewable energy projects. These projects might have the potential not only to generate expansive[47] but also contractive effects that could affect energy-intensive sectors such as manufacturing (Hillebrand et al. 2006). This contractive effect describes how the expansion of renewable energy could increase electricity prices and might affect manufacturing production costs, leading to a fall in production as well as a decrease in sectoral employment (Aldy et al. 2011). The net total result on local employment, which is the sum of direct, indirect and induced employment, will depend on how much the contractive effect offsets the positive impact at the local level (Wang et al. 2013).

A second issue is that although renewable energy projects generate demand for manufacturing goods and services, it is likely that these goods have to be imported from other regions because specific manufacturing components are not produced everywhere; so this might benefit other localities outside the project's site (Adas 2003; del Rio and Burguillo 2008; Brown et al. 2012).

Therefore, the cross-sectoral employment generation may not necessarily stimulate and promote local industry. Finally, a third issue is related to the durability or temporariness of the employment generated during project's life (Brown et al. 2012). Although these projects may contribute to job creation, not all renewable energy technologies might be able to generate sustained employment effects at the local level (Komor and Bazilian 2005). That might be the case for wind projects, which may greatly stimulate job creation mainly during construction phase, but not significantly during operation and maintenance stage (Simas and Pacca 2014); in contrast, biomass projects might tend to generate more stable job positions because of the extent of its production chain (del Rio and Burguillo 2008).

Regarding empirical studies, there are two main groups of research that have assessed the impacts of CDM projects on local employment. They can be classified into ex-ante and ex-post evaluations. Ex-ante studies are the most predominant type of assessments in the empirical literature on CDM;

[47] An expansive effect describes an increase in production and employment as a result of an investment, in this case, in renewable energy. In contrast, a contractive effect refers to a decrease in demand and thus in production (Hillebrand et al. 2006).

these are mainly qualitative studies that use PDD data for the analysis, which is data based on potential or expected project results. In contrast, there are very few ex-post assessments that used empirical data and have applied quantitative techniques. Most common methodologies applied in ex-ante studies are checklists (Olsen and Fenhann 2008), scoring pattern methods (Subbarao and Lloyd 2011) or the Multi Criteria Assessment (MCA) method (Sutter 2003) and its further adaptations. Regarding main findings, these are inconclusive. Some studies have reported positive contributions at the local level (Olsen and Fenhann 2008; UNFCCC 2011; Udin et al. 2015), while some have found no effects associated with the implementation of CDM projects (Sutter and Parreño 2007; Alexeew et al. 2010; Subbarao and Lloyd 2011).

As already argued in the introduction, ex-post empirical studies on local employment effects are much scarcer. Du and Takeuchi (2018) estimate the impacts of CDM in rural communities in China by combining a difference-in-differences model with propensity score matching techniques. Findings show that while CDM biomass projects have stimulated local job creation also for unskilled laborers, large-scale CDM hydro and solar projects have contributed to employment generation in primary industry at the local level. A comparatively smaller literature assesses economy-wide employment effects by using CGE models and input-output models. With a global CGE model, Mattoo et al. (2009) assessed the impacts of climate change financing on the industrial sector in developing countries and reported that CDM host countries may experience reductions in the manufacturing output and exports due to Dutch disease-type effects. Wang et al. (2013) applied an input-output model to estimate the impacts of CDM energy projects in China and showed that although CDM has caused direct job losses, it has also created indirect jobs. These impacts differed by project type: wind and biomass energy projects showed positive and significant effects in indirect employment generation that offset the negative effect in direct employment. In contrast, hydro projects had both direct and indirect job losses, particularly in the secondary energy industry and the mining industry.

In the particular case of Brazil, very few quantitative assessments have been conducted yet in the context of CDM. For instance, with a focus on development and poverty indicators, Mori Clement (2018) estimated impacts of CDM across Brazilian municipalities and identified a positive effect on

labor and income indexes[48] for biomass, landfill and methane avoidance projects. Again using data from the PDDs as well as stakeholders' interviews, Fernandez et al. (2014) find that CDM projects have succeed in delivering positive employment effects in the short-term, during construction and operation phase, but failed to promote long-term benefits in some Brazilian states.

3. Registered CDM projects in Brazil

Brazil is a pioneering country in hosting CDM projects worldwide. The first CDM project was registered in Rio de Janeiro in November 2004, a landfill gas project located in the municipality of Nova Iguacú. As of 2015, there are totally 338 CDM projects registered in the Executive Board (UNEP 2015). They can be divided according to their sectoral scope into two main categories: renewable energy or power projects (60%) and waste handling and disposal projects (35%). The rest of CDM investments (5%) are projects in the chemical and manufacturing industries.

Main project types in the renewable energy or power sector are hydro (45%), wind (27%) and biomass energy (22%); most predominant project's subtypes in this sector are: run-of-river hydroelectric power (hydro projects), wind (wind projects) and bagasse power (biomass energy projects). Regarding the waste handling and disposal sector, methane avoidance (56%) and landfill gas (44%) projects are the most representative types; while main project's subtypes in this sector are landfill flaring, landfill power (landfill gas projects), and manure (methane avoidance). In terms of geographic distribution of projects along the Brazilian territory, the distribution by macro region is quite uneven (see Table 1). Macro regions where CDM projects were implemented are the South-east with 39.3% of the total; the North-east with 21.6%, the South with 19.2% and the Central-west with 14.5%. Few projects (5.6%) were implemented in the North (Amazonian), region characterized by its very high forest density.

More than 50% of renewable energy projects are located in the South-east and South region (30.4% and 22%, respectively), while 28% in the North-east. In the case of waste handling and disposal projects, 51% of total are located in the South-east, 18% in Central-west and 17% in the

[48] These income-labor indicators are aggregated indexes at the municipal level; no sectoral effects were estimated.

South. Almost 80% of the CDM projects in the North-east are investments in the renewable energy sector; this reflects the high potential of this region to host energy projects such as hydro and wind. Moreover, the distribution of CDM projects reflects a general division of the country, where the south and southeast are much more developed and industrialized than the north (Fernandez et al. 2012). At the national level, 7.6% (or 425 municipalities) has at least one CDM project that was implemented during period 2004-2014. This number exceeds the total number of registered CDM projects (338) because some projects involved more than one municipality.

Table 1: CDM projects by Brazilian macro regions: number of projects by type (Period: 2004-2014)

Region	Number of CDM Projects	%	CDM project type					
			Hydro	Wind	Biomass energy	Landfill gas	Methane avoidance	Other
North	18	5.3	9	0	2	3	1	3
North-east	73	21.6	5	47	6	8	4	3
Central-west	49	14.5	26	0	2	0	20	1
South-east	133	39.3	26	0	29	33	27	18
South	65	19.2	28	9	7	7	12	2
Total	**338**	**100**	**94**	**56**	**46**	**51**	**64**	**27**

Source: UNEP (2015).

Regarding the temporal development of CDM investments in Brazil, the number of registered CDM projects started decreasing from 2013. One driver was the collapse of the CER prices which started in 2012[49], with prices in secondary markets remaining at very low levels (Ecofys 2014). A crucial determinant in this trend was the introduction of an EU restriction in the use of international credits under the Phase III of the EU-ETS (2013-2020), where only CERs from projects registered

[49] Main determinants behind the collapse of the CER prices were the Eurozone debt crisis, which led to a decrease in the industrial activity in the region, and the over-allocation of emission allowances under the European Union Emissions Trading Scheme (EU ETS), the most important market in driving global CER demand (Yu et al. 2012).

after 2012 are eligible if they were hosted by Least Developed Countries[50] (LDCs) (Ecofys 2013). As a consequence, the overall size of CDM investments to Brazil declined relative to the period before.

Despite the collapse of CER prices in 2012 and thus the high risk of project discontinuity due to disincentives to invest in verification and issuance of these credits, most CDM projects in Brazil continued running (Warnecke et al. 2015a). According to Warnecke et al (2017), this is due to the fact that some project types are particularly resilient to the development of the CER price. Projects with high capital investment, such as hydro, wind or solar, experienced a low vulnerability of discontinuity due to high revenues for electricity sales as well as low operating costs. However, other project types, such as biomass energy and methane avoidance, may experience variable vulnerability, due to project subtype and local specific conditions (e.g. renewable energy prices, supply's reliability, among others).

4. Methodological approach

4.1. Data

In order to assess the impacts of CDM projects on employment, we investigate effects on total and cross-sectoral employment at the municipality level using a dynamic panel regression model for period 2004-2014. A detailed description of all variables is displayed in Table 2. Regarding employment variables, we use the total employment growth rate, which is the annual growth rate of total employment[51] at the municipality level. To explore cross-sectoral effects, we evaluate impacts on sectoral employment shares for the following sectors: industry, agriculture, services, construction and commerce. The selection of these sectors is based on the empirical literature on renewable energy projects and its potential effects on sectoral employment (see section 2). Main source of employment data is the Brazilian Ministry of Labor and Employment (MTE) from the Annual Report on Social Information (RAIS).

[50] In addition, CERs from subtype projects such as HFC and adipic acid are not longer permitted after April 2013 (Kossoy and Guigon 2012; Ecofys 2013).

[51] Total employment encompasses data on eight sectors: mining, manufacturing, services in the industry, construction, commerce, services, agriculture and public administration.

Table 2: Variables description

Variable	Description	Type	Source
Total employment growth rate (i,t)	Annual growth rate total employment (municipality)	Dependent	MTE
Employment share in the industry sector (i,t)	Annual employment share in the industry sector (municipality)	Dependent	MTE
Employment share in the agricultural sector (i,t)	Annual employment share in the agricultural sector (municipality)	Dependent	MTE
Employment share in the services sector (i,t)	Annual employment share in the services sector (municipality)	Dependent	MTE
Employment share in the construction sector (i,t)	Annual employment share in the construction sector (municipality)	Dependent	MTE
Employment share in the commerce sector (i,t)	Annual employment share in the commerce sector (municipality)	Dependent	MTE
CDM (i,t)	Dichotomous variable: 0 = municipality without a CDM project at time *t* 1 = municipality with a CDM project at time *t*	Explanatory	UNEP
CER credits (i,t)	Dichotomous variable: 0 = municipality with a CDM project that did not generate CER credits at time *t* 1 = municipality with a CDM project that generated CER credits at time *t*	Explanatory	UNEP
Time-dummy: CER crisis	Dichotomous variable: 0 = Before CER crisis (2004-2012), 1 = After CER crisis (2013-2014)	Explanatory	
Total real GDP growth rate (i,t)	Annual total GDP growth rate (municipality)	Explanatory	IBGE
Industry real GDP growth rate (i,t)	Annual GDP growth rate in the industry sector (municipality)	Explanatory	IBGE
Agriculture real GDP growth rate (i,t)	Annual GDP growth in the agricultural sector (municipality)	Explanatory	IBGE
Service real GDP growth rate (i,t)	Annual GDP growth in the service sector (municipality)	Explanatory	IBGE

'i' municipality, 'j' federate state, 't' year

Table 2: Variables description (cont.)

Variable	Description	Type	Source
Population growth rate (i,t)	Annual population growth (municipality)	Explanatory	IBGE
Total real GDP growth rate (j,t)	Annual total GDP growth (federate state)	Explanatory	IBGE
Industry real GDP growth rate (j,t)	Annual GDP growth in the industry sector (federate state)	Explanatory	IBGE
Agriculture real GDP growth rate (j,t)	Annual GDP growth in the agricultural sector (federate state)	Explanatory	IBGE
Service real GDP growth rate (j,t)	Annual GDP growth in the service sector (federate state)	Explanatory	IBGE

'i' municipality, 'j' federate state, 't' year

Regarding explanatory variables in the model, we use a proxy variable for CDM which is a dichotomous variable[52] that assigns "1" to those municipalities with a CDM project at time *t*; this starts from project's registration[53] year onwards. Before the CDM registration, a "0" was assigned. In our analysis, only municipalities with one CDM project have been included in order to avoid potential bias due to cross-effects from other CDM projects[54]. Two category of projects were analyzed: a) hydro (renewable energy sector), and b) methane avoidance (waste handling and disposal sector)[55]. To distinguish municipalities with and without CDM projects, first, we use the database from the CDM pipeline (UNEP), which is a database at the project level that provides information about the municipality where each project has been implemented (as well as registration year, project type, project scale, among others project's features). Once we have identified those municipalities with CDM projects by year, this database was merged with other datasets (e.g. employment data, demographic data) in order to build the panel. In a last step, we split the sample into two sub-samples:

[52] CDM investment values were also considered to be used as CDM proxy variable in our analysis. However, since investment data were only available for a few number of observations, we decide to use the dummy variable as proxy for CDM investment.
[53] The starting date of CDM project activities (e.g.: construction) occurs after a project's registration. Thus, employment effects could be observed from the year of the project's registration or in the next following years depending on how fast the project is implemented.
[54] From the 425 municipalities with CDM investments, 349 municipalities had only one project.
[55] Other project's types such as wind, biomass and landfill gas were not included in the analysis due to sample issues.

municipalities with CDM hydro projects and with CDM methane avoidance projects A detailed table with the total number of municipalities with CDM investments for both project types at the federate state level is provided in the Appendix (see Table A.1).

Table 3: Descriptive statistics

Variable	Mean	Sd	Min	Max	N	T
Employment share - Industry	0.20	0.18	0	0.89	204	11
Employment share - Agriculture	0.15	0.14	0	0.86	204	11
Employment share - Service	0.15	0.10	0	0.81	204	11
Employment share - Construction	0.03	0.07	0	0.90	204	11
Employment share - Commerce	0.17	0.09	0	0.39	204	11
Municipal GDP share – Industry	0.20	0.17	0	0.90	204	11
Municipal GDP share – Agriculture	0.23	0.17	0	0.80	204	11
Municipal GDP share – Services	0.35	0.13	0	0.76	204	11
FE[1] GDP share – Total	0.01	0.03	0	0.40	204	11
FE[1] GDP share – Industry	0.01	0.03	0	0.63	204	11
FE[1] GDP share – Agriculture	0.01	0.01	0	0.13	204	11
FE[1] GDP share – Service	0.01	0.02	0	0.41	204	11

[1]FE: Federate state

To evaluate the effect of CER credits on the local economy we use a dichotomous variable, where "1" indicates that a municipality has a CDM project that generated CER credits at time *t* or during its corresponding crediting period. Through this variable, we attempt to capture activity of CDM projects in terms of CER credits issuance. Data on CDM and CER credits come from the CDM Pipeline Analysis and Database of the United Nations Environment Programme (UNEP). To capture a potential structural break after the collapse of the CER price, we introduce a dummy variable which takes the value of "0" before the crisis (2004-2012) and "1" afterwards.

Regarding other explanatory variables relevant for general trends in employment generation, we include both economic (i.e. total and sectoral GDP growth at the municipal and federate state level[56])

[56] To decide whether which GDP level (municipal vs. federate state) will be used, we run GDP regression models for municipalities with both project types to test the significance of CDM on municipal GDP. In the case of hydro, as CDM does not show any significant impact on GDP growth, we use municipal GDP as explanatory variable in the sectoral employment

as well as demographic indicators such as population growth at the municipal level[57]. All economic and demographic data come from the Brazilian Institute of Geography and Statistics (IBGE). Some descriptive statistics are displayed in Table 3. Further details on employment and GDP growth at the federal state level in municipalities with CDM projects can be found in figures A.1 and A.2 in the Appendix.

4.2. Methodology

The potential impacts of CDM projects on employment may take some time to come into effect; therefore, the impact of lagged CDM variables were analyzed through a dynamic panel model for period 2004-2014 across Brazilian municipalities where CDM projects were implemented. This econometric model estimates cross-sectoral effects of CDM projects on local employment over time. The dynamic panel model is estimated using instrumental variable technique, so a Generalized Method of Moments (GMM) approach (Arellano and Bond 1991) is applied. Equation (1) describes this model (Bond 2002), where $y_{i\,t-1}$ is the autoregressive term, x_{it} is a set of explanatory variables which could also include a lagged structure of them; ρ_i represents unobserved individual-specific effects, while ε_{it} is an error term.

$$y_{it} = \alpha\, y_{i\,t-1} + \beta\, x_{it} + \rho_i + \varepsilon_{it} \qquad (1)$$

The unobserved individual-specific effects are correlated with the autoregressive term by construction; thus, the Arellano-Bond estimator is constructed by first differencing to remove the panel-level effects and using instruments to form moment conditions. Lagged values of the dependent

models. In contrast, in the case of methane avoidance, we use GDP at the federate state level as explanatory variable in the sectoral employment models. These regressions are displayed in the appendix (see Table A.2 for hydro and Table A.3 for methane avoidance).

57 In accordance with the neoclassic labor demand theory, labor depends also on factor prices. As data on wage rates were not accessible at the municipality level, this variable was not included in the model.

variable are used to form the GMM-type instruments. One important model assumption is that the error terms are independent across individuals, so they are serially uncorrelated.

Although the coefficients of the autoregressive component (or the lagged dependent variable) are not directly interpreted, its incorporation allows for dynamics that might be relevant for recovering consistent estimates of other parameters in the model (Bond 2002). Some advantages of using GMM are that it can correct for unobserved heterogeneity, omitted variables bias as well as potential endogeneity problems (Bond et al. 2001). Regarding the no serial autocorrelation assumption, when testing validity, we calculate the Arellano-Bond test for first and second-order serial autocorrelation in the first-differenced residuals, which tests the null hypothesis of no autocorrelation. The Wald chi-squared test is also included to test for joint validity of the models. The regression analysis is run using Stata software version 14 and command "*xtabond2*". Results are displayed and discussed in the next sections.

5. Results

To estimate cross-sectoral effects of CDM projects on municipal employment over time, we run the dynamic regression models separately for two subsamples: municipalities with hydro projects (table 4) and municipalities with methane avoidance projects (table 5). In both cases, we estimate models of the impacts on sectoral employment (i.e.: industry, agriculture, services, construction and commerce sectors). Other model specifications[58] are displayed in the Appendix section.

Results for the hydro project subsample (table 4) show a negative and significant impact in the immediate CDM coefficient on total employment growth at the municipality level. Other significant explanatory variables in this model are the autoregressive term, total municipal GDP growth as well as population growth. No significant effects are found for the the CER proxy and the time dummy for

[58] In the appendix, we include regression models without the lagged CDM variable to estimate the "overall" effect of CDM on sectoral employment (Table A.4 and Table A.5). In addition, we also estimate municipal GDP models to test how CDM may affect GDP growth (Table A.2 and Table A.3). Although the impact of CDM on municipal GDP is not a goal for this research, we run these GDP models to decide whether we need to include control variables at the federate state level. We find that CDM does not have a significant impact on municipal GDP in municipalities with hydro projects, but this is not the case for methane avoidance projects, where we found also small and transitory effects of CDM on municipal GDP. For this reason, we use municipal GDP as explanatory variable in the employment models for hydro, while in the case of methane avoidance, we use federal state GDP

the CER crisis in 2012. At the sectoral level, we find effects of CDM on industry, agriculture and commerce employment models; while no effects in the service and construction models.

In the industry employment model, the CDM coefficient depicts small and significant effects in its 2-year and 3-year lags, meaning that CDM projects had a delayed indirect positive impact on manufacturing employment during the 2nd year after registration of the project and then this effect turned negative during the 3rd year.

A CDM project could potentially contribute to generate employment at the local level through direct and/or indirect job creation during construction, operation and maintenance phases (UNFCCC 2012), but could also have a contractive effect in some industries (Wang et al. 2013). With respect to this positive effect, the transitory impact found during the 2nd year after registration of the project in the industry employment model is in line with the empirical research on the impacts of renewable energy projects other than the CDM framework, where most significant and positive benefits of hydro projects on local employment took place during construction phase (Reddy et al. 2006; Koschel 2013; Chandy et al. 2013). This temporary effect during construction phase can be explained by the generation of demand for intermediate goods and services in the industry (Brown et al. 2012).

While this mechanism explains the positive effect of CDM projects in the second-year lag, we find a negative sign for the third-year lag in the industry employment model. For this negative effect, there are two potential explanations. This can be due to a temporal overshooting effect, meaning that employment increase in the second period is partially offset by a slight decline in the third period, e.g. because employment is redirected from other industry production rather than generating additional employment by CDM. Another potential explanation is that the demand for manufacturing goods might not take place within the project's municipality (del Rio and Burguillo 2006; Brown et al. 2012); thus some degree of manufacturing imports might be experienced (Adas 2003; Aldy 2011), with potential negative effects on local industry.

Table 4: Regression models: CDM hydro

Explanatory Variables	(1) Total employment Growth	(2) Industry employment share	(3) Agriculture employment share	(4) Service employment share	(5) Construction employment share	(6) Commerce employment share
AR(1)	-0.16***	0.50***	0.14	0.53***	0.10	0.14*
	(0.04)	(0.07)	(0.17)	(0.08)	(0.09)	(0.08)
CDM	-0.034**	0.001	-0.012**	-0.006	-0.005	0.007***
	(0.016)	(0.004)	(0.005)	(0.006)	(0.004)	(0.002)
CDM Lag 1	0.024	-0.004	-0.002	0.009	0.005	0.006**
	(0.024)	(0.004)	(0.003)	(0.006)	(0.007)	(0.003)
CDM Lag 2	-0.014	0.008*	0.009	-0.003	0.002	0.002
	(0.012)	(0.005)	(0.006)	(0.005)	(0.006)	(0.003)
CDM Lag 3	-0.027	-0.009***	-0.007	0.009	-0.008	0.005
	(0.018)	(0.004)	(0.004)	(0.007)	(0.009)	(0.003)
CER	0.003	0.005*	0.003	0.008*	0.005	-0.001
	(0.02)	(0.003)	(0.004)	(0.005)	(0.005)	(0.003)
Time dummy: CER crisis	-0.04	0.004	0.003	-0.001	-0.006	0.008
	(0.09)	(0.003)	(0.004)	(0.006)	(0.007)	(0.003)
Total GDP growth (municipality)	0.13***					-0.006*
	(0.04)					(0.003)
GDP industry growth (municipality)		0.002**			0.011**	
		(0.001)			(0.004)	
GDP agriculture growth (municipality)			0.002			
			(0.002)			
GDP services growth (municipality)				0.017**		
				(0.009)		
Population growth (municipality)	-0.28**	-0.007	0.04	0.007	0.02	0.02
	(0.13)	(0.03)	(0.04)	(0.02)	(0.05)	(0.02)
Time dummy: CER crisis	-0.04	0.004	0.003	-0.001	-0.006	0.008
	(0.09)	(0.003)	(0.004)	(0.006)	(0.007)	(0.003)
Obs	791	791	791	791	791	791
m1	-5.04	-3.82	-1.49	-1.94	-2.19	-2.97
m2	-1.01	-0.22	1.64	-0.86	-0.86	0.50
Wald test	52.6	70.8	24.0	91.4	9.2	35.2

Other significant explanatory variables in the industry employment model are the autoregressive term and the industry GDP growth at the municipal level, whose effects are positive as expected according to theory. Moreover, a small and positive effect which is significant at the 10% level is found for the CER proxy on industry employment, while no significant effect is identified for the time-dummy for the CER crisis. This means that CER revenues generated employment and that this effect persisted even after the decline of the CER price in 2012. This finding is less surprising when considering that nearly 80% of hydro CDM projects in Brazil started before 2012, so that a considerable short term effect on employment was already realized before the crisis.

In the agriculture employment model, CDM hydro projects show a negative and significant impact only in the immediate coefficient. A possible explanation for this indirect and temporary cross-sectoral effect is that agricultural wage rates are lower than in other sectors and that therefore employment could be relocated from agriculture to other sectors like commerce and industry. No significant impacts are found for the CER proxy on agricultural employment and the time dummy for the CER crisis.

Regarding the service sector, as mentioned before, no CDM effects were found. Since hydro projects are very capital intensive, consequently, sectors such as service may not necessarily benefit from job creation. Although the CDM does not show any significant impact, the CER proxy depicts a small and positive effect, which is significant at the 10% level. Other significant explanatory variables in the model are the autoregressive term and the GDP growth in the service sector. No significant effect was identified for the time-dummy for CER crisis. Similarly, no CDM effects were found in the construction employment model. The only significant variable in the construction model is GDP growth in the industry sector.

Finally, regarding the commerce model, the CDM shows a small and positive impact in the immediate and 1st lagged coefficient, which means that CDM has contribute to generate a positive induced effect that reached this sector. The positive employment effect found within the commerce sector could be generated by induced employment effects due to the wage income generated by hydro projects. The only other significant variable in the commerce model is municipal GDP growth.

Results for the methane avoidance subsample (table 5) show significant effects of CDM in both total and sectoral employment at the municipality level. In the case of total employment growth, the coefficient of the CDM variable depict a small, but significant impact in the immediate term, so municipalities with CDM projects exhibit negative and transitory effects directly after project's registration. This negative effect of CDM projects on total employment growth may be driven by a contractive effect in some sectors (most notably agriculture) that outweighs the positive effects in other sectors (construction, commerce, service). Other significant explanatory variables in the total employment growth model are the autoregressive term, total federal state GDP growth as well as population growth. No significant effects are found for the CER proxy and the time dummy for the CER crisis in 2012.

At the sectoral level, transitory effects of CDM projects on employment are found in the agriculture, services, construction and commerce sectors, but no impacts for the industry employment model. For the agricultural employment model, the impact of methane avoidance CDM projects is significant and negative in the registration's year, while no significant effects are reported for any lagged CDM variables. Other significant variables in this model are the autoregressive term, agricultural GDP growth and population growth (at the 10% level).

In the case of the service employment model, the immediate term and the lag structure of the CDM variable present significant effects up to the second lag. This may reflect employment demands generated during the construction and operation phase. Methane avoidance projects involve more labor intensive and low-skilled activities provided by other sectors; consequently, the service sector can directly benefit from job creation through activities that do not require high qualifications such as collection, separation, among others. This effect alternates, starting from positive, turning negative and then positive. This can be again due to a temporal overshooting effect. Other significant variables in this model are the autoregressive term and the GDP growth rate in the service sector.

Table 5: Regression models: CDM methane avoidance

Explanatory variables	(1) Total employment Growth	(2) Industry employment share	(3) Agriculture employment share	(4) Service employment share	(5) Construction employment share	(6) Commerce employment share
AR(1)	-0.16***	0.14*	0.26**	0.35***	0.22 **	0.33***
	(0.04)	(0.14)	(0.13)	(0.08)	(0.11)	(0.11)
CDM	-0.035**	0.003	-0.016**	0.016 **	0.005**	0.007**
	(0.016)	(0.005)	(0.006)	(0.007)	(0.003)	(0.003)
CDM Lag 1	0.024	-0.001	0.009	-0.009 *	0.002	-0.002
	(0.024)	(0.005)	(0.009)	(0.005)	(0.005)	(0.003)
CDM Lag 2	-0.014	0.005	-0.0004	0.006 **	0.002	-0.006
	(0.012)	(0.005)	(0.005)	(0.003)	(0.002)	(0.002)
CDM Lag 3	-0.026	-0.003	-0.003	0.002	0.0003	-0.007
	(0.018)	(0.003)	(0.009)	(0.004)	(0.003)	(0.003)
CER	0.003	0.003	-0.007	-0.006	-0.003	-0.001
	(0.02)	(0.004)	(0.009)	(0.006)	(0.005)	(0.003)
Time dummy:	-0.024	0.008	0.012	-0.002	0.008	-0.003
CER crisis	(0.02)	(0.005)	(0.009)	(0.004)	(0.006)	(0.003)
Total GDP growth (Federate State)	0.13***					
	(0.04)					
GDP industry growth (Federate State)		0.004			0.023**	
		(0.005)			(0.012)	
GDP agriculture growth (Federate State)			0.022***			
			(0.008)			
GDP services growth (Federate State)				0.06**		0.03*
				(0.03)		(0.02)
Population growth (Municipality)	-0.28**	0.05	-0.09*	-0.04		-0.02
	(0.13)	(0.034)	(0.059)	(0.031)		(0.02)
Obs	630	630	630	630	630	630
m1	-5.04	-2.86	-2.84	-2.49	-2.16	-4.09
m2	-1.02	1.14	0.96	0.64	0.29	1.01
Wald test	53.1	8.6	37.6	66.3	37.6	31.2

Significance level: *** at 1%, ** at 5%, * at 10%

m1, m2: tests for first and second-order serial correlation respectively, for the first-differenced residuals.

The construction and the commerce employment models show a significant and positive impact of CDM also in the immediate coefficient and no significant effects are found for lagged CDM variables. The proxy for CER credits does not show any significant impact in any methane avoidance model. Although some CDM projects promised to share carbon revenues from the generation of CER credits with the municipal government to further contribute to the local development, it seems that the transfer may have not taken place. A potential explanation of this insignificant effect is that this rent was probably captured by the private sector in several ways (Martinez and Bowen 2012). Similarly, no significant effects are found for the time dummy for the CER crisis in 2012 on total and sectoral employment.

6. Discussion and conclusions

The regression analysis showed that CDM projects in Brazil had mixed and transitory effects in sectoral employment at the local level. The ability of CDM investments to create employment opportunities depends on several variables such as technology type and project's stage. Based on the assessment of two CDM project types, our analysis shows that CDM hydro projects have a small, but mixed impact on industry employment, positive impact in commerce employment, while a negative impacts in agricultural employment. No CDM effects are found in other sectors such as services and construction. Regarding CDM methane avoidance projects, although no impacts are identified on industry employment, small but significant and temporary effects are identified for the agriculture, service, construction and commerce employment. In general, for both hydro and methane avoidance projects, effects in employment are mainly temporary.

In accordance with the literature on renewable energy impacts on employment, we therefore find that the cross-sectoral effect of CDM projects on employment is mixed. This is also in line with empirical evidence on the consequences of a shift from traditional to green technologies which will require adjustments to the labor market, which in turn may modify labor demand (e.g. new skills requirements), thus configuring a situation with winners and losers, in particular in carbon-intensive sectors (ILO/OECD 2012). Depending on whether the direct employment effect is presumed to be strong, such as for landfill gas or biomass energy which are relatively labor intensive, or whether this

direct employment effect is presumed to be small, as for capital-intensive technologies like wind or hydro, sustained and significant impacts along a project's lifetime may emerge for some projects but not for others (Sutter and Parreño 2007; Subbarao and Lloyd 2011). Our findings for hydro projects are also in line with some empirical analysis of the impacts of hydro investments on employment, whose effects were very modest and temporary (Reddy et al. 2006; Chandy et al. 2012) and impacted negatively some industries (Wang et al. 2013).

In addition to the type of technology and project stage, employment effects of implementing renewable energy projects will also depend on the interdependency that already exists among economic sectors at the local level (Hillebrand et al. 2006), as well as on local socio-economic conditions, resource endowments and cultural features (Reddy et al. 2006; Dhakal and Raut 2011). Therefore, before implementation of any renewable energy or waste management project, part of the challenge is to identify local needs as well as resource potentialities in order to choose a suitable technology with a value chain that could contribute to enhance local economic performance (Martinez and Bowen 2012). Only when a project type matches the local conditions, both positive direct and indirect employment effect may be generated and thus a net positive effect on overall employment, instead of only a shift of employment from one sector to the other, may be found.

Regarding the impacts of CER credits on employment, we find no significant results for methane avoidance, but a very small, positive and slightly significant influence in industry and service sectors in municipalities with hydro projects. Although some CDM projects promised to share carbon revenues from the generation of CER credits with municipal governments to further contribute to the local development, it seems that transfers may have not taken place; probably these inflows were captured by the private sector in several ways (e.g.: used to pay part or the whole financial loan acquired to implement the CDM project). If these revenues were spent at the local level, induced employment effects could be generated due to additional demand.

Regarding of the impact of the CER crisis, we find that this dummy variable has no significant impact on sectoral employment for both project types. An explanation for this result is provided by Warnecke et al (2017), who argue that projects with high capital investment such as hydro

experienced a low vulnerability of discontinuity due to high revenues for electricity sales as well as low operating costs.

Given the heterogeneous level of economic growth among developing countries, further research might attempt to investigate impacts not only in emerging economies like Brazil, but also in least developed countries to compare effects under different socio-economic conditions and resource endowments. Moreover, one potential further explanation why CDM projects generate employment in some municipalities but not in others is the role of the local government which could attract or deter potential investors. Political and institutional barriers have been found important in case study research on CDM projects (see, e.g. Luthra et al., 2015, for India). Therefore, the influence of the political process at the local level should be investigated in more detail in future research. Finally, as this is one of very few ex-post studies that have attempted to estimate the impacts of CDM over time using real data, more case study research is needed on understanding the mechanisms that drive cross-sectoral employment effects, particularly on the dynamics and cross-sectoral interactions at the local level.

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Appendix A.1. Municipalities with CDM projects at the federate state level

Table A.1: Distribution of CDM municipalities across federate states (Period: 2004-2014)

Macro region	Federate state	Municipalities	
		Hydro	Methane avoidance
North	Amapa	2	
North-east	Bahia	1	
South-east	Espiritu Santo	3	2
Central-west	Goias	7	3
South-east	Minas Gerais	31	14
Central-west	Mato Grosso do Sul	2	14
Central-west	Mato Grosso	12	6
North	Para	1	
South	Parana	5	7
South-east	Rio de Janeiro	9	
North	Rondonia	3	
South	Rio Grande do Sul	22	8
South	Santa Catarina	12	18
South-east	Sao Paulo	4	18
		114	**90**

Appendix A.2. Regressions with municipal GDP as dependent variable

Table A.2: Municipal GDP growth rate model: CDM Hydro projects

Explanatory Variables	(1) Total GDP growth	(2) Industry GDP growth	(3) Agriculture GDP growth	(4) Service GDP growth
AR(1)	-0.17***	-0.11**	-0.29***	-0.14***
	(0.04)	(0.04)	(0.05)	(0.05)
CDM	0.04	0.02	-0.01	0.006
	(0.03)	(0.14)	(0.07)	(0.02)
CDM Lag 1	0.019	-0.12	0.08	0.02
	(0.03)	(0.18)	(0.05)	(0.02)
CDM Lag 2	-0.01	0.05	-0.003	-0.02
	(0.03)	(0.06)	(0.05)	(0.02)
CDM Lag 3	-0.001	-0.02	-0.06	-0.002
	(0.03)	(0.09)	(0.05)	(0.02)
CER	-0.001	-0.06	0.01	-0.01
	(0.02)	(0.07)	(0.03)	(0.02)
Time dummy:	0.07	0.10	-0.02	0.03
CER crisis	(0.05)	(0.01)	(0.04)	(0.03)
Total GDP growth	0.828 ***			
(Federate state)	(0.25)			
GDP industry growth		0.97 **		
(Federate state)		(0.11)		
GDP agriculture growth			0.67 ***	
(Federate state)			(0.13)	
GDP services growth				0.78***
(Federate state)				(0.16)
Population growth	0.43**	1.11	0.53	0.05
(Municipality)	(0.19)	(0.32)	(0.51)	(0.19)
Obs	791	791	791	791
m1	-2.59	-3.49	-2.71	-3.31
m2	-1.00	-0.75	-1.19	0.19
Wald test	54.5	23.6	52.9	48.0

Significance level: *** at 1%, ** at 5%, * at 10%

m1, m2: tests for first and second-order serial correlation respectively, for the first-differenced residuals.

Table A.3: Municipal GDP growth rate model: CDM Methane avoidance projects

Explanatory Variables	(1) Total GDP growth	(2) Industry GDP growth	(3) Agriculture GDP growth	(4) Service GDP growth
AR(1)	-0.09	-0.05	0.24***	-0.16*
	(0.06)	(0.06)	(0.05)	(0.09)
CDM	-0.03	0.02	-0.05	-0.007
	(0.03)	(0.05)	(0.05)	(0.03)
CDM Lag 1	-0.005	-0.007	-0.008	0.003
	(0.02)	(0.05)	(0.04)	(0.02)
CDM Lag 2	-0.03	-0.005	0.004	-0.06**
	(0.02)	(0.05)	(0.03)	(0.02)
CDM Lag 3	0.04*	0.02	0.13*	0.09***
	(0.02)	(0.05)	(0.07)	(0.03)
CER	0.02	-0.03	-0.05	0.004
	(0.017)	(0.05)	(0.04)	(0.02)
Time dummy:	-0.01	0.08	0.03	0.008
CER crisis	(0.01)	(0.07)	(0.04)	(0.03)
Total GDP growth	1.07 ***			
(Federate state)	(0.18)			
GDP industry growth		0.58***		
(Federate state)		(0.13)		
GDP agriculture growth			1.19 ***	
(Federate state)			(0.11)	
GDP services growth				0.86***
(Federate state)				(0.23)
Population growth	0.27 *	-0.18	0.03	0.17
(Municipality)	(0.16)	(0.28)	(0.37)	(0.19)
Obs	630	630	630	630
m1	-5.08	-5.02	-4.72	-2.82
m2	-1.12	-1.39	-1.80	0.29
Wald test	95.1	48.5	24.4	34.9

Significance level: *** at 1%, ** at 5%, * at 10%

m1, m2: tests for first and second-order serial correlation respectively, for the first-differenced residuals.

Appendix A.3. Regressions without the CDM lagged structure

Table A.4: Regressions without the CDM lagged structure: CDM Hydro projects

Explanatory Variables	(1) Total employment growth	(2) Industry employment share	(3) Agriculture employment share	(4) Service employment share	(5) Construction employment share	(6) Commerce employment share
AR(1)	-0.14	0.54***	0.25*	0.46***	0.31***	0.18**
	(0.07)	(0.07)	(0.14)	(0.09)	(0.08)	(0.08)
CDM	-0.06	-0.002	-0.016**	0.004	-0.001	0.013***
	(0.04)	(0.004)	(0.008)	(0.005)	(0.005)	(0.003)
CER	-0.05	0.002	0.001	0.006	0.007	-0.008
	(0.021)	(0.003)	(0.004)	(0.004)	(0.006)	(0.003)
Time dummy:	-0.04	0.002	0.006	0.000	-0.008	-0.002
CER crisis	(0.03)	(0.003)	(0.004)	(0.005)	(0.005)	(0.003)
Total GDP growth	0.13**					
(municipality)	(0.08)					
GDP industry growth		0.003*			0.011***	
(municipality)		(0.004)			(0.003)	
GDP agriculture growth			0.005			
(municipality)			(0.002)			
GDP services growth				0.017**		-0.006**
(municipality)				(0.008)		(0.003)
Population growth	-0.27*	-0.003	0.05	0.03	0.04	0.01
(municipality)	(0.15)	(0.02)	(0.06)	(0.03)	(0.06)	(0.02)
Obs	912	912	912	912	912	912
m1	-2.71	-4.63	-2.84	-3.69	-2.60	-3.27
m2	1.29	1.27	2.11	0.06	-0.42	1.84
Wald test	8.3	64.3	38.7	34.6	25.0	34.8

Significance level: *** at 1%, ** at 5%, * at 10%

m1, m2: tests for first and second-order serial correlation respectively, for the first-differenced residuals.

Table A.5: Regressions without the CDM lagged structure: CDM Methane avoidance projects

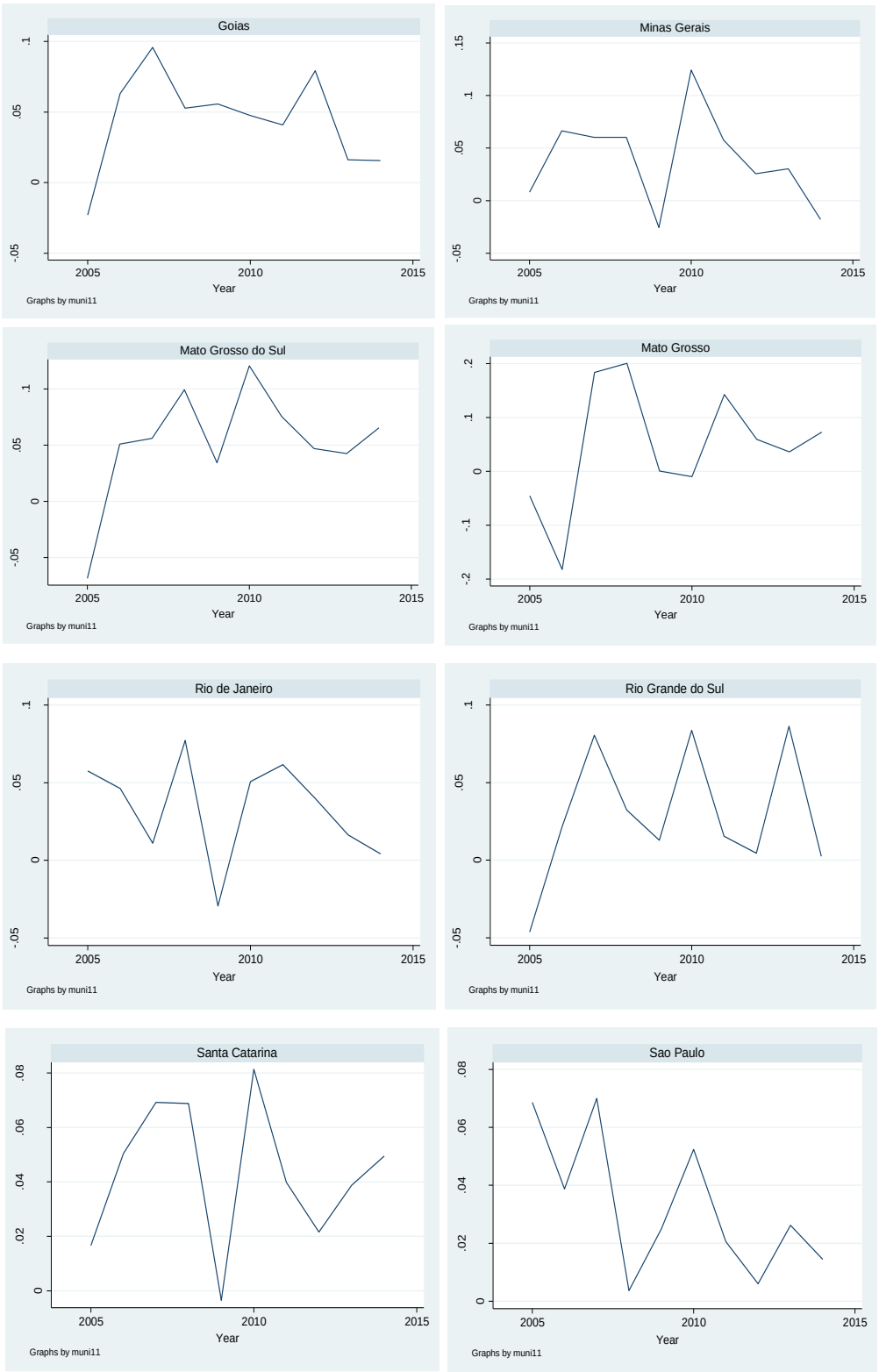
Explanatory Variables	(1) Total employment Growth	(2) Industry employment share	(3) Agriculture employment share	(4) Service employment share	(5) Construction employment share	(6) Commerce employment share
AR(1)	-0.18	0.18	0.33***	0.46***	0.16 **	0.32***
	(0.05)	(0.11)	(0.09)	(0.12)	(0.07)	(0.09)
CDM	-0.05***	-0.001	-0.019**	0.004	0.003	0.007**
	(0.019)	(0.005)	(0.007)	(0.006)	(0.003)	(0.003)
CER	-0.002	0.007	-0.004	-0.009	0.002	-0.008
	(0.02)	(0.005)	(0.006)	(0.006)	(0.004)	(0.002)
Time dummy:	-0.025	0.002	0.003	-0.004	-0.002	-0.002
CER crisis	(0.016)	(0.005)	(0.008)	(0.004)	(0.004)	(0.002)
Total GDP growth (Federate State)	0.12*** (0.04)					
GDP industry growth (Federate State)		0.01 (0.02)			0.023**(0.011)	
GDP agriculture growth (Federate State)			0.011 (0.008)			
GDP services growth (Federate State)				0.04* (0.03)		0.03* (0.01)
Population growth (Municipality)	-0.32 *** (0.12)	0.03 (0.03)	-0.08* (0.05)	-0.07 (0.03)	-0.005 (0.02)	-0.02 (0.02)
Obs	720	720	720	720	720	720
m1	-4.82|	-3.77	-3.66	-3.40	-1.85	-3.82
m2	-1.28	1.43	1.06	1.40	-0.81	-0.21
Wald test	24.6	11.4	42.7	52.8	22.9	33.5

Significance level: *** at 1%, ** at 5%, * at 10%

m1, m2: tests for first and second-order serial correlation respectively, for the first-differenced residuals.

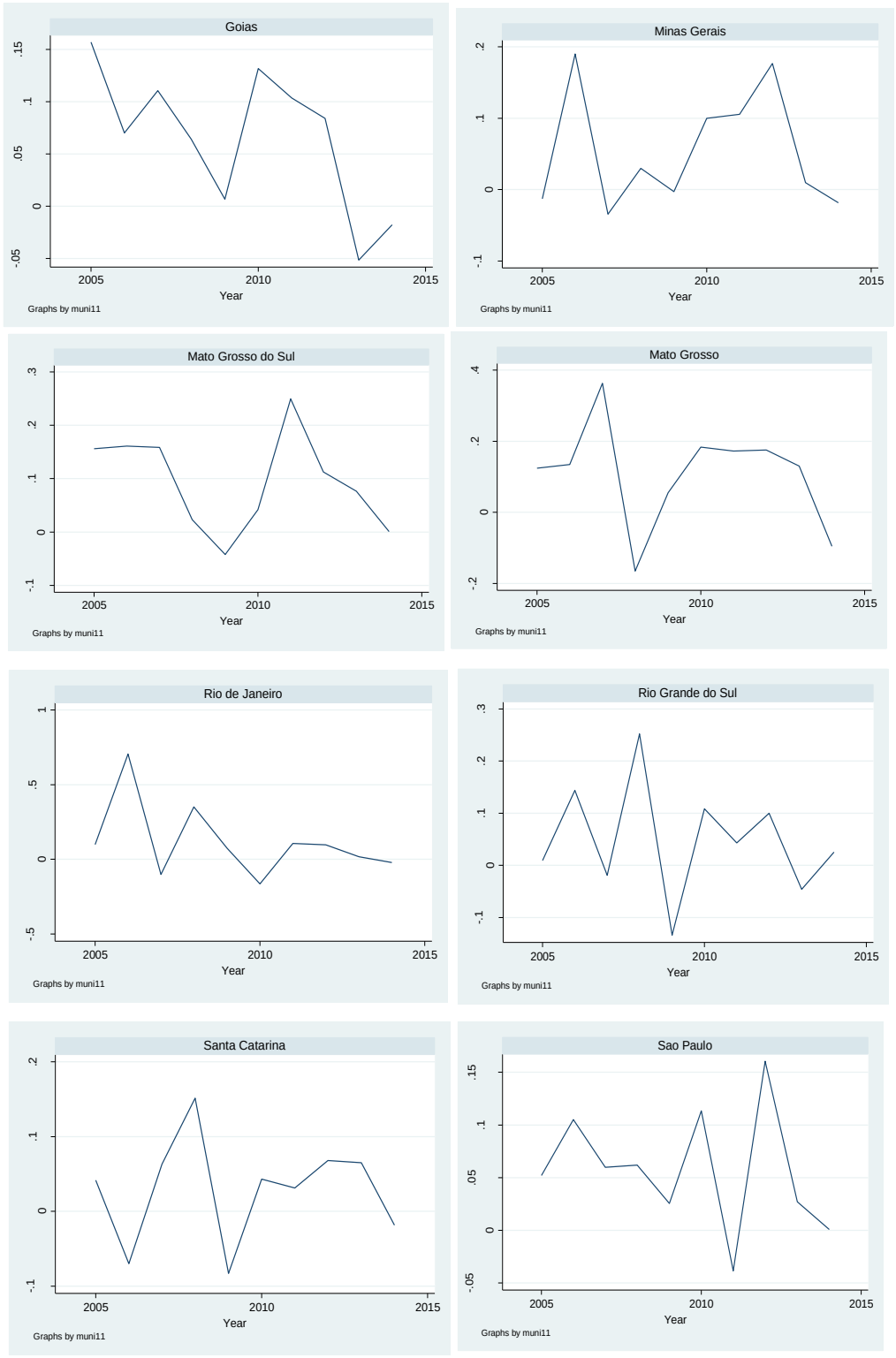
Appendix A.4. Trends in real GDP and employment

Figure A.1: Real GDP growth in federate states with the highest number of municipalities with CDM hydro and methane avoidance projects (2004-2014)



Note: The selected federate states concentrate nearly 82% of municipalities with CDM hydro projects and 71% of municipalities with methane avoidance projects.

Figure A.2: Employment growth in federate states with the highest number of municipalities with CDM hydro and methane avoidance projects (2004-2014)



Note: The selected federate states concentrate nearly 82% of municipalities with CDM hydro projects and 71% of municipalities with methane avoidance projects.

4.4. Paper 3

Mori-Clement, Y.; Nabernegg, S. and B. Bednar-Friedl (2018): Can preferential trade agreements enhance renewable electricity generation in emerging economies? A model-based policy analysis for Brazil and the European Union. Grazer Economic Paper (preparation for submission to the journal *Climate Policy*)

Can preferential trade agreements enhance renewable electricity generation in emerging economies? A model-based policy analysis for Brazil and the European Union

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Abstract

Preferential trade agreements with climate-related provisions have been suggested as alternative to a New Market Mechanism due to its potential not only to achieve Nationally Determined Contributions (NDCs) in emerging economies but also to lead to more ambitious targets in the first UNFCCC global stocktake in 2023. The objective of this research is therefore to analyze the effectiveness and quantify the economic impacts of such a trade agreement between Brazil and the European Union that aims to support renewable electricity generation. Using a multi-regional computable general equilibrium model, we find that the environmental effectiveness of a preferential trade agreement targeting renewable electricity generation strongly depends on its design. In particular, preferential trade agreements require additional elements to effectively contribute to mitigation as the sole removal of import tariffs on renewable energy technology is quite ineffective in scaling up the share of wind, solar, and biomass in Brazil. In contrast, a preferential trade agreement triggering FDI flows towards renewable electricity generation is effective in increasing the share of renewables in the generation mix and in reducing CO_2 emissions, while positively affecting the Brazilian economic performance. Finally, we compare the two previous approaches to a domestic energy policy: a combination of higher fossil fuel taxes and subsidies to renewable electricity generation. We find that although this domestic energy policy is more effective in mitigation terms than the FDI policy, economic performance is negatively affected in several sectors. When such economic costs are socially not acceptable, as it is likely in many emerging economies, properly designed preferential trade agreements could therefore be a suitable instrument for supporting the achievement of NDCs, and potentially increase their stringency for the next stock taking period.

Keywords: Preferential Trade Agreements with climate-related provisions, Environmental Goods, Renewable Energy, FDI, Emerging Economies, Brazil, European Union

1. Introduction

Although the Paris Agreement (2015) represents a significant step in global climate negotiations, the implementation of the current Nationally Determined Contributions (NDCs) may not be sufficient to achieve the 2°C target (Boyd et al. 2015; Rogelj et al. 2016; Schleussner et al. 2016). Estimations show that although these voluntary contributions may lower greenhouse gas (GHG) emissions, these reductions may lead to achieving a median warming of 2.6-3.1°C by 2100 (Rogelj et al. 2016). Thus, additional measures and actions have to be taken by all countries in order to keep global warming below the 2°C target. Since Durban (2011), the need for new market-based mechanisms (NMM) has been discussed, which go beyond mere offsetting and can achieve net emission reductions through scaling up mitigation actions in broad segments[59] of developing countries' economies (UNFCCC 2012)[60].

Although Article 6 of the Paris Agreement establishes and encourages voluntary cooperation among parties to achieve their NDCs through a *mechanism* (Article 4.4), no other specifications regarding its characteristics and nature are mentioned in the Accord[61]. As an alternative to the NMM, some scholars have therefore proposed preferential trade agreements (PTAs) with climate-related provisions (Dong and Whalley 2010, 2011; Leal-Arcas 2013, 2015; Brandi 2017; Morin and Jinnah 2018). Bilateral arrangements may enhance not only accessibility but also dissemination of goods that could contribute to achieving mitigation objectives through the removal of import and non-tariff barriers (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017). Trade liberalization of environmental goods[62] has the potential to decrease pollution abatement costs, thus generating incentives to adopt cleaner technologies in the importing country, while boosting markets of these goods in the exporting country.

In the context of the Paris Agreement, trade elements have been incorporated in the NDCs to deal with climate contributions. Although almost all NDCs include references that can be related to trade, nearly 45% made it directly, but only 22% included trade-specific measures (Brandi 2017)[63]. Most common trade-related references include targeting the renewable energy sector (100%), focusing on technology transfer (63%) and using international market mechanisms (56%). To a much less extent, tools such as trade regulations on climate grounds[64] (11%) and the removal of trade barriers (6%) were included. Regarding trade barriers, concrete measures were included such as the reduction of

[59] What broad segments means, has to be defined by Parties and it may encompass sectoral and/or project-specific basis (UNFCCC 2013).

[60] In the literature, diverse options for NMM have been discussed (Sterk and Mersmann 2012; Gao et al. 2016): 1) project-based or also known as enhanced CDM or CDM plus (Brazil 2014), 2) NAMA crediting , 3) sectoral market mechanisms (Baron et al. 2009; Schneider and Cames 2009; Dransfeld et al. 2011; Schneider et al. 2014), and 4) bilateral crediting systems (Warnecke et al. 2015). All these proposals for NMM are not free of challenges and barriers .

[61] This *mechanism*, which also shares the twofold objective of the old CDM, is also informally called in the literature as the Sustainable Development Mechanism (SDM) (Marcu 2016).

[62] Although there is no a common-agreed definition of "environmental goods" (and services) due to complexities in defining this sector (Vossenaar 2016), it could encompass those goods (and services) used "*to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related waste, noise and eco-systems*" (UNSTATS/OECD 1999, p.9). Therefore, it may include all those goods (and services) related to clean-technologies, energy efficiency, pollution control, among others (Bucher et al. 2014). In addition to that, it might include low carbon products for final consumption as well as inputs to produce (and consume) low-carbon products (Dong and Whalley 2010).

[63] Brandi (2017) identified eleven trade-related elements, which are classified as follows: reducing trade barriers, regulating trade on climate grounds, regulating timber trade, standards and labelling, border carbon adjustments, renewable energy, fossil fuel subsidy reform, international market mechanisms technology transfer and response measures (Brandi 2017).

[64] This trade element has been included as NDC by Antigua and Barbuda, Bahamas, Republic of Congo, Cook Island, Djibouti, Eritrea, Gabon, Haiti, Kuwait, Mauritania, Namibia, Nigeria, Saint Lucia, Samoa, South Sudan, Togo, Tuvalu and Venezuela.

import duties on renewable energy equipment[65] or tariff reductions in specific vehicles such as electric cars[66]. These measures have been proposed by several small countries[67]. Other trade instruments, such as the adoption of Border Carbon Adjustments, were explicitly considered by only one Party (i.e., Mexico).

In the present paper, we therefore analyze the potential and the effectiveness of preferential trade agreements with climate-related provisions for Brazil, an emerging economy with steadily rising CO_2 emissions over the last decades and NDCs that are according to the Climate Action Tracker insufficient with keeping global warming below the 2°C target (Climate Action Tracker 2018). Still, the marginal abatement costs (as percentage of GDP) of implementing the NDCs are highest for Brazil within the 10 most emitting countries (Hof et al. 2017) In its NDCs, Brazil targets the renewable energy sector as priority sector for mitigation, with a domestic target of increasing the share of renewables in the generation energy mix to 45% by 2030 through the expansion of solar, wind, biomass and hydro[68]. Although Brazil's NDCs are not dependent on international support, additional actions would require large-scale increase of international involvement through investment flows as well as technology transfer and diffusion, so the country "welcomes support from developed countries with a view to generate global benefits" (Brazil 2016, p.3).

In the case of top emitters such as the EU, although its NDCs do not explicitly refer to trade-related measures, the EU has been actively involved in incorporating climate-related provisions in its PTAs with emerging and developing economies in the last decades (Morin and Jinnah 2018). Some examples of climate-related provisions adopted are the removal of trade and non-trade barriers on climate goods and services relevant to mitigation (EU-Colombia and Peru 2012; EU-Korea 2010; EU-Georgia 2014), cooperation in the renewable energy sector (EU-Mexico 1997; EU-CARIFORUM 2008; EU-Central America 2012; EU-Georgia 2014; EU-Singapore 2014); promotion of foreign direct investment (FDI) in environmental technologies and services (EU-Korea 2010; EU-Central America 2012) or strengthening carbon market mechanisms (EU-Central America 2012)[69].

The objective of this research is therefore to analyze and quantify the impacts of a bilateral preferential trade agreement with climate-related provisions between Brazil and the EU. In particular, we look into two elements of such provisions: (i) removal of import tariffs on renewable energy equipment; and (ii) promotion of climate-related foreign direct investments. To put these policies into perspective, we compare them to a domestic renewable energy policy. This paper is structured as follows: section 2 reviews the literature on trade and climate with a focus on preferential trade agreements; section 3 provides some background information on current mitigation policies in Brazil. The methodological approach as well as selected scenarios are outlined in section 4, while section 5 displays results. Policy implications and conclusions are drawn in section 6.

[65] This specific trade measure has been proposed by Guyana and Lao.
[66] This specific trade measure has been proposed by Bahamas, Saint Lucia, and Saint Vincent and the Grenadines.
[67] By the moment, the reduction or removal of trade barriers in their NDCs has been included by Bahamas, Cuba, Djibouti, Guyana, Lao PDR, Niue, Saint Lucia, Saint Vincent and the Grenadines, Seychelles and Togo.
[68] Other measures explicitly included as part of the NDCs are the increase of sustainable biofuels in energy mix to 18%, strengthening policies targeting land use and forests, the promotion of new standards in clean technology and low carbon infrastructure in the industry sector as well as improvements in infrastructure in urban areas in the transportation sector. In addition, Brazil reserves the right for the possibility to use international market mechanisms.
[69] At very less extent, other climate-related provisions are the ratification and implementation of Kyoto Protocol (EU-Montenegro 2007), cooperation on adaptation to climate change (EU-Moldova 2014) and an agreement to address fossil fuel subsidies (EU-Singapore 2014).

2. Literature review

2.1. Impacts of trade liberalization on emissions

Trade liberalization may affect the environment through three main channels (Grossman and Krueger 1991); Copeland and Taylor 2004). The first channel is the scale effect or expansion of economic activity due to trade, which leads to an increase in energy use and thus in emissions. The second channel is the composition effect, which explains how trade liberalization may alter the domestic production structure; the direction of this effect depends on country's comparative advantages in emission-intensive sectors as well as on whether these sectors are expanding (or contracting). Finally, the technique effect explains how trade may contribute to reduce emissions by improving the way of producing (and consuming) goods through enhanced availability of low-carbon goods and technologies.

Via the technique effect, trade liberalization may create new opportunities for emerging markets such as those on low-carbon or environmental goods and cleaner technologies through two mechanisms (Grossman and Krueger 1993). First, a tariff removal on these goods will reduce the costs of cleaner technologies, contributing to its disseminating and transfer; second, trade may also increase income levels and thus the demand for low-carbon goods. Moreover, trade liberalization may also generate incentives to producers to increase their production on low-carbon goods and thus export them (Claro and Lucas 2007).

Empirical studies on trade openness and their effects on carbon dioxide emissions have been inconclusive (Cole and Elliot 2003; Managi 2004; Frankel and Rose 2005; Managi et al. 2008; Hubbard 2014; Ertugrul et al. 2016). Although some studies estimated increasing emissions due to the prevalence of scale effects (Cole and Elliot 2003; Frankel and Rose 2005; Managi 2004), other studies have found differences across group of countries, e.g., OECD versus non-OECD (Managi et al. 2008).

Due to the increasing recognition of the potential of trade to contribute to sustainable development goals, the Doha declaration (2001) called for the reduction or elimination of tariff and non-tariff barriers to environmental goods and services (EGS)[70] to improve their access. However, difficulties in outlining an approach to a multilateral reduction due to diverse interests as well as diverging positions on the benefits from trading these goods have prevented progress on this matter (Balineau and de Melo 2013; Sauvage and Timiliotis 2017). Well before Doha, the OECD[71] and the APEC[72] started working on elaborating their respective lists of environmental goods. Although these lists were designed with different purposes[73], both have contributed to frame WTO negotiations on this particular topic (Steenblick 2005; Sugathan 2013).

[70] Products considered under this classification targeted air pollution control, renewable energy, waste management as well as water and wastewater treatment (WTO 2018).

[71] The OECD list includes 164 goods and it encompasses clean technologies, products and services to decrease environmental risk and pollution as well as resource use (Bucher et al. 2014).

[72] The APEC list consists of 54 product subheadings used in solving, limiting or preventing environmental problems (Bucher et al. 2014). This list may include parts and components to generate electricity from renewable energy sources, equipment for filtering/purifying water, among other products (Vossenaar 2016).

[73] The purpose of the OECD list was to enhance the understanding of the dimensions of the environment industry, while APEC list was designed to facilitate negotiations on this matter (Steenblick 2005).

2.2. Preferential Trade Agreements with climate-related provisions

A bilateral or multilateral arrangement in the form of a PTA is a reciprocal trade agreement which grant preferential access to each other's markets favoring members through the reduction of tariff barriers and less stringent non-tariff barriers (Leal-Arcas 2015). In the last two decades, the incorporation of environmental provisions in these agreements has been rising, not only in number but also in scope and level of stringency (Jinnah and Morgera 2013); this rise offers room for innovative climate-supportive trade rules to deal with mitigation targets (Holzer and Cottier 2015; Brandi 2017).

PTAs hold a high potential to contribute to climate mitigation as they exhibit attributes of trade negotiations that could shape them as strong instruments (OECD 2007; Gehring et al. 2013; Morin and Jinnah 2018). First, the reduced number of participants may accelerate the bargaining processes; second, the direct reciprocity allows introducing sanctions and thus enhancing compliance. Third, PTAs also allow flexibility for policy experimenting with the possibility of yearly re-negotiations. Finally, they can directly contribute to address trade-related mitigation issues. Easing access and diffusion of environmental goods, services and technologies achieved through PTAs, may contribute to climate change mitigation objectives (ICTSD 2011; Sugathan 2015; Sauvage and Timiliotis 2017).

The basic form of a PTA with environmental/climate-related provisions would include a removal of trade barriers (e.g., import tariffs) on low-carbon and environmental goods. Other climate-related provisions that may be incorporated into the negotiation of a PTA are the harmonization of low-carbon standards, removal of fossil fuels subsidies, the promotion of climate-related investments (e.g.: in renewable energy technologies) and technology transfers and other forms of cooperation such as FDI inflows (Holzier and Cottier 2015; van Asselt 2017; Brandi 2017).

PTAs may promote FDI (Büthe and Milner 2008; Medvedev 2011), which in turn could also contribute to mitigation targets through the transfer and dissemination of cleaner technologies (Corfee-Morlot et al. 2009; UNCTAD 2010; Buchner et al. 2011). Moreover, FDI has also a high potential to deliver positive effects for the environment through technology leapfrogging and spill-overs to domestic firms though the dissemination of good practices (Gallagher and Zarsky 2007). Empirical literature on FDI and its impacts on mitigation is still limited. Most studies test the pollution haven and the halo effect hypotheses[74] (Zhu et al. 2016). Available findings are inconclusive; some research supports reductions in emissions (Merican et al. 2007; Zhu et al. 2016; Shao 2017), while other studies do identify increase in emissions (Merican et al. 2007, Jorgenson 2007; Acharyya 2009; Behera and Dash 2017) or no effects (Perkins and Neumeyer 2009).

Currently, 85% of the PTAs contain at least one environmental provision[75] (DIE 2017), of which 14% address climate-specific issues. Most of these climate-related provisions focus on promotion of renewable energy and/or energy efficiency[76] and very few provide sanctions in case of non-compliance (Morin and Jinnah 2018). In general, most environmental provisions are not trade-related, thus they are treated as a separated issue from the trade agreement (Morin and Jinnah 2018). Some

[74] The pollution haven hypothesis (Chichilnisky 1994) tests whether FDI flows to host countries with less stringent environmental standards, while the pollution halo effect hypothesis (Dean 1992) tests whether FDI leads to positive externalities to the environment through the spread of clean technology and climate-friendly practices.

[75] Beside climate-related provisions, most environmental provisions address issues on biodiversity, waste and water management, fisheries, forests, deserts and ozone (Morin and Jinnah 2018). Biodiversity is by far the issue-area with most replication in several PTAs.

[76] Morin and Jinnah (2018) identified eight types of climate-related provisions in PTAs. In addition to the promotion of renewable energy and energy efficiency technologies, other provisions that directly address climate change have focused on cooperation on climate governance, reduction of GHG emissions, adaptation to climate change, ratification or implementation of climate agreements (e.g., Kyoto, UNFCCC) and harmonization of climate regulations.

reasons behind are, for instance, the potential high costs as a result of more stringent mitigation measures as well as political feasibility (Anuradha 2011; Leal-Arcas 2013).

Regarding evaluations of PTAs, there are few assessments available. Literature can be divided into quantitative and qualitative research. Most studies have focused on the NAAEC[77] or the environmental side agreement of the NAFTA. Regarding quantitative studies, one of the first assessments of the NAFTA was conducted by Grossman and Krueger (1991). Using a CGE model, they analyzed the compositional effect of the NAFTA on pollution (sulphur dioxide) in Mexico; results showed that there was no evidence of environmental degradation. In contrast, other studies show opposing results. Gallagher (2004) argued that environmental conditions worsened in Mexico, leading to an increase in sulphur and carbon dioxide emissions. This study also discusses the shortcomings of the NAAEC to deal with environmental issues. Similarly, using econometric techniques, Yu et al. (2011) also found a significant increase in emissions not only in Mexico but also in the US after 1994. Dong and Whalley (2011) used a multi-region general equilibrium model[78] to evaluate the impact of a tariff reduction on low-carbon intensive goods. They find that tariff reductions have a positive but quantitatively small impact on emission reductions and explain this effect by economic growth, which fuels emissions more than trade and its composition. Regarding qualitative studies, some have reported the acceleration of environmental reforms in some countries that negotiated PTAs with environmental provisions; that is the case of Singapore (FTA US-Singapore 2003); Chile (FTA US-Chile 2003) or Morocco (FTA US-Morocco 2004) (OECD 2007).

3. Current policies in Brazil to support renewable electricity generation in the context of the NDCs

According to the Brazilian NDCs, it is intended to reduce GHG emissions by 37% below 2005 levels in 2025 and by 43% in 2030. The renewable energy sector is priority for mitigation with a domestic target of increasing the share of renewables in the energy mix to 45% by 2030, which includes expanding the use of renewable sources (other than hydro) in the total energy share between 28% and 33% by 2030, and increasing the share of renewable (other than hydro) in the power supply to at least 23% by 2030 (Brazil 2016).

The Brazilian electricity sector is the largest in South America. Renewable energy sources account for almost 80% of total electricity generation and hydropower represents 65%, while biomass 9.4%, wind 6.7% and solar 0.02% (EPE 2017b). As the energy mix strongly relies on hydropower, this makes Brazil vulnerable to power supply shortages in drought years as it was the case in 2001, 2012 and 2015 (Krishnaswamy and Stuggins 2007; Schmidt et al. 2016). Therefore, energy mix diversification should be considered as backbone strategy to enhance energy security and decrease reliance on fossil fuels (da Silva et al. 2016). Although the share of other renewable energy sources such as wind and solar are still low in the energy mix (6.7% and 0.02%, respectively), its potential is

[77] The North American Agreement on Environmental Cooperation (NAAEC) is an environmental agreement between the US, Canada and Mexico. It came into effect in 1994. The NAAEC contains a declaration of principles and objectives regarding conservation and environment protection.

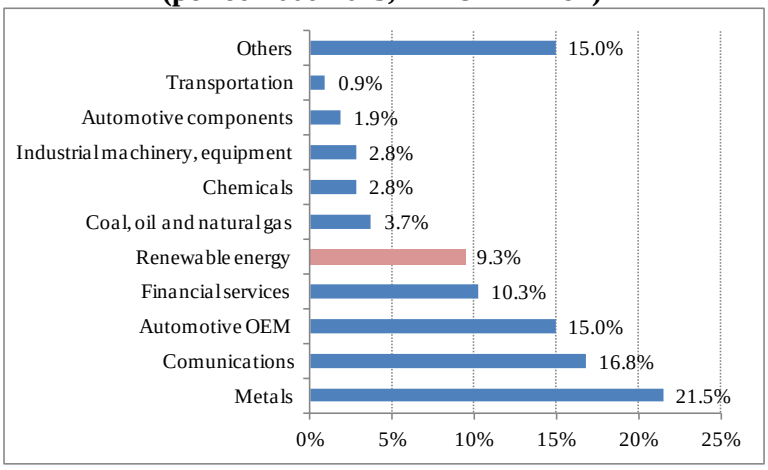
[78] This model covers trade for US, EU, China and the rest of the world. The high-emission sector is represented by the manufacturing sector, while the low-emission sector includes service and agriculture.

very large[79] (CRESESB 2001; Bueno et al. 2006); this makes Brazil an attractive market for investments in renewable energy technologies.

Regarding incentives for investments in the renewable energy sector, the Program of Incentives for Alternative Electricity Sources (PROINFA) launched in 2002 has played a role in promoting wind, biomass and small hydropower plants in Brazil. Nearly 95% of projects have been financed by this program by 2011 (Pereira et al. 2012). Although solar was excluded from PROINFA, the government considered it as beneficiary of short-term fiscal incentives in the form of tax exemptions and import tax reductions[80] through the Special Taxation Regime of Incentives for the Development and Production of Alternative Energy Source (REINFA). However, promotion of solar energy is still weak (Ferreira et al. 2018). In addition, there are still obstacles to promote technologies other than hydro such as high transmission and integration costs (Schmidt and Guedes-Ribeiro 2018).

With respect to fossil fuels, oil and natural gas are subject to several taxes at the federal, state and municipal level (OECD 2014). Some examples are the CIDE fuel consumption tax (for imports and retail sales) and social security contributions such as the PIS (Program of Social Integration) and the COFINS (Social security financing contribution). However, producers may also enjoy tax exemptions under several incentive regimes[81] to promote investments in the sector (OECD 2014; Nuamy-Barker 2015). In addition, oil producers are exempted from the payment of corporate income taxation: the corporate income tax (IRPJ) and the social contribution tax on profits (CSLL) according to the new tax regime law established in 2017 (INESC 2018).

Figure 1: Share of sectoral greenfield investment by the EU in Brazil (period 2006-2015, in EUR million)



Source: APEX-BRASIL (FDI Markets 2016).

[79] The Brazilian North-East is the region with the strongest wind potential during the dry or winter season, which coincides with the season of lower rainfall intensity in the year (CRESBS 2001). Moreover, solar potential is greater in summer, period of the year when energy demand increases (Jong et al. 2013). These seasonal complementarities offer a great opportunity to diversify energy sources as well as represent a challenge how to integrate renewable and intermittent energy sources into the electricity sector (Oliveira et al. 2017).

[80] This includes exemptions of the state value-added tax (ICMS) and social integration/social security contribution taxes (PIS/COFINS) on net electricity as well as import tariff reductions from 14% to 2% on capital goods and related components.

[81] Some examples are the Special Incentive Regime for Infrastructure Development (REIDI) which exempt companies from paying social security contributions such as the PIS and the COFINS on goods for infrastructure projects, the Special Tax Regime for Goods used in the Exploration (REPETRO) which exempt companies from the PIS, the COFINS and the IPI (Excise duty on industrialized products) when importing goods by sea for research activities and extraction or the (REPORTO) which exempt companies from the PIS; the COFINS and the IPI when investing in port infrastructure.

In terms of trade, the EU is Brazil's second largest trading partner accounting for almost 20% of its total trade in 2016[82] (EuroStat 2017). Its trade with the EU accounts for 30.8% of the EU's total trade with Latin America. This relevance is not only reflected in trade but also in FDI considering that Brazil is the third EU's main FDI inflow destination worldwide (APEX-BRASIL 2017). At the sectoral level (Figure 1), the estimated announced productive FDI[83] in renewable energy by the EU in Brazil represents 9.3% of the total for period 2006-2015 (FDI Markets 2016).

4. Methodology

To investigate the macroeconomic effects of different PTA instruments we use a multi-regional multi-sectoral computable general equilibrium model. This kind of model is state of the art for investigating the effects of trade agreements and environmental policy and are widely applied in the literature (see e.g., Böhringer et al. 2015; Klepper and Peterson 2006). We consider this model especially suited for our analysis because of its representation of regional and sectoral details of the economy, as well as international trade linkages.

4.1. Model

The CGE model, based on Nabernegg et al. (2017) and Schinko et al. (2014), represents the structure of an economy by national and international trade flows organized by regions and sectors. In each region agents interact on the supply and demand side of different markets. Further technical specifications of the model can be found in the appendix.

Figure 2 shows the basic flows for one model region (r). The regional household is endowed with the primary factors of labor (L), capital (K), and natural resources (R). These primary factors are used in the domestic production process, that uses also intermediate inputs (ID_{ir}) from all other sectors (i). The primary factors are assumed to be perfectly mobile between the different sectors, but immobile between regions. Sectoral firms are assumed to produce under perfect competition and provide their produced output for exports (EX_{irs}) to other regions (s) or domestic supply. The different degree of substitutability between sectoral inputs is captured by nested constant elasticity of substitution (CES) functions for each sector. For the preferences between domestically produced and imported products we follow the Armington assumption (Armington, 1969), which treats sectoral products from different regions as imperfect substitutes. Sectoral imports (IM_{irs}) and domestic production are therefore grouped in an Armington aggregate (G_{ir}), which feeds into the domestic supply (D_{ir}). Finally, the domestic supply is demanded by other firms as intermediate inputs and as final demand (FD_{ir}) of the regional household. Households optimize their consumption level given their income from labor, capital, and natural resources. Final demand (by households and the government) is represented by nested CES functions in the model.

[82] EU imports from Brazil are dominated by primary products, (i.e., foodstuffs, beverages and tobacco products (18.2%), vegetable (17.9%) and mineral products (16.3%)), while EU exports are mainly on machinery and appliances (26.6%), chemical products (23.6%) and transport equipment (13.6%).

[83] According to FDI Markets, this data on announced productive FDI represents all greenfield investment projects or new productive investments made by existing companies

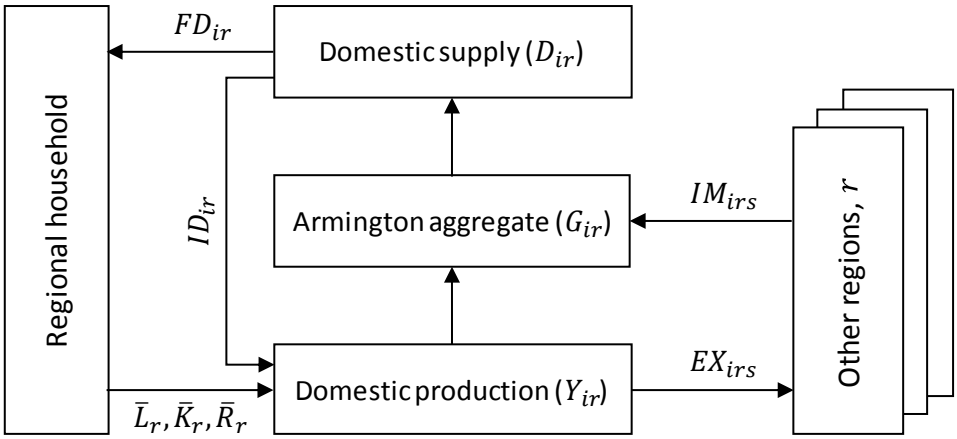


Figure 2: Economic representation in each region of the CGE model. FD_{ir} …Final demand, ID_{ir}…Intermediate demand, $\bar{L}_r$…Labor endowment, $\bar{K}_r$…Capital endowment, $\bar{R}_r$…Natural resource endowment, IM_{irs}…Imports, EX_{irs}…Exports

For the calibration of the model, we use economic data from the Global Trade Analysis Project (GTAP) Version 9 (Aguiar et al. 2016). The latest year of data, that we use as benchmark, is 2011. Substitution elasticities for sectoral production functions are specified from different studies from the literature (Aguiar et al. 2016; Beckman and Hertel, 2010; Okagawa and Ban, 2008). To reduce complexity and computational intensity, we aggregate the data provided by GTAP for 140 regions and 57 sectors to 10 regions and 25 economic sectors (see Appendix for aggregation list). Regions include Brazil, Europe and their most important trading regions (e.g., USA, China, Mercosur), as well as other main economic regions.

The electricity sector on the other hand is further disaggregated into different production technologies as well as transmission and distribution, to allow for an investigation of climate and energy related instruments. To differentiate across generation technologies, we use data on installed and generation capacity by technology from the Brazilian Energy Research Office (EPE 2017a, 2017b). Together with information on Levelised Cost of Electricity (LCOE) for each technology from Jong et al. (2015) and Silva et al. (2016) we can then calculate their monetary output values and assign the residuals to the sector of transmission and distribution. Note that these LCOEs estimates draws on case study data from 13 projects for several renewable energy technologies in Brazil. Fuel-specific inputs from the aggregated electricity sector are attributed to the corresponding disaggregated production technology of coal, oil, gas and nuclear power. We further use the investment costs provided in Jong et al. (2015) and Silva et al. (2016) to assign the corresponding capital inputs as share of total inputs for each technology. Other intermediate inputs are distributed proportionally to the output values of the technology and adapted manually to match input-output equality. Each of the disaggregated production technologies is implemented with fixed input shares (zero elasticities of substitution), while we allow for a high substitution between the technologies (see Appendix for further specifications).

Combustion emissions of CO_2 in the CGE model are depicted by sector-specific coefficients and linked with a zero elasticity of substitution to the use of fossil fuels. Additionally, we include industrial process emissions, emerging from chemical or physical processes in the production of steel, cement, and chemical products. Data on combustion emissions are included in the GTAP database

and complemented with Eurostat data. Industrial process emission data comes from the UNFCCC database and CDIAC.

4.2. Policy scenarios

We base our scenario design in the context of the NDC of Brazil and compare the contributions of two aspects of climate related provisions in PTAs and a domestic energy policy to reduce carbon emissions by the expansion of renewable electricity generation.

The first policy scenario (*Preferential Trade Agreement*) is characterized by reductions in direct trade barriers for renewable electricity technologies, such as wind turbines or photovoltaic panels, between the EU and Brazil. In particular, we assume that import tariffs for such technology imports are removed which should increase the installation of renewable electricity capacities using European technology at reduced costs.

The second policy scenario (*Foreign Direct Investment*) considers that a preferential trade agreement includes the promotion of European FDI in renewable electricity generation in Brazil. While over the past decade renewable energy was already targeted by European FDI to some extend (see: Section 3), we consider such investment to increase substantially in this scenario. The distribution of investment between the different renewable electricity technologies is assumed to continue its latest pattern of high wind and solar shares. In this scenario, we set the level of European FDI that is consistent with the Brazilian NDC target for 2030 which demands a combined share of renewable electricity supply from wind, biomass, and solar of 23%.

In the third policy scenario (*Domestic Energy Policy*), we investigate a change in domestic energy taxes in Brazil. Here we assume that the relationship between fossil fuel and renewable electricity taxes is adjusted towards the relationship in Europe. While in Brazil fossil fuel use in industry and electricity production is currently much less taxed than electricity from renewable sources, in the EU there is a much smaller gap between these tax rates on fossil and renewable sources of energy (OECD 2018). The adapted tax regime for this scenario is set up as revenue neutral in which revenues from increased fossil fuel taxes finance subsidies for renewable electricity production.

The promotion of FDI in renewable electricity technologies (*Foreign Direct Investment* scenario) is implemented in the CGE model as additional European capital input in the renewable electricity sectors in Brazil. The FDI is calibrated to increase the share of renewable electricity other than hydro from currently 15% to 23%, fulfilling the NDC target for 2030. Additionally, we increase the capital effectiveness of FDI compared to the domestic capital input, reflecting lower European interest rates and continued technological progress, especially in solar technology. In the scenario of domestic policy in Brazil (*Domestic Energy Policy* scenario), we implement a revenue neutral combination of an increase in fossil fuel taxes and reduction of renewable electricity taxes. We exogenously increase the tax rates in the fossil fuel sectors of coal, crude oil, gas and refined oil and coal products to a level, which reflects the European relation of fossil fuel taxes to electricity taxes. The additionally generated tax revenue is used as subsidy to the renewable electricity sectors, with the subsidy rate determined endogenously in the model to guarantee revenue neutrality. This procedure results in a tax increase on fossil fuels, most relevant for refined oil and coal products, from 0.4% to 3.9% which is on a similar level as tax rates in this sector e.g., in other Latin American region or the US. The revenue recycling leads to an overall subsidy rate of 17% for the renewable electricity production.

5. Results

Figure 3 illustrates the electricity generation mix across generation technologies for the base year (2016) and the three policy scenarios. In the base year, 81.5% of electricity in Brazil is generated from renewables, with the largest contribution from hydro (66.6%), and comparatively smaller contributions from biomass (8.7%) and wind (6.2%) while the share of solar is negligible (0.01% of total generation mix). In two policy scenarios, the share of both wind and solar is increased: The *Foreign Direct Investment* scenario leads to an increase in wind (11% of total generation mix), biomass (11%), solar (3%), and also to a small increase in hydro (67.7%). This increase in the share of wind and solar is due to the fact that FDI flows are resource specific, where a relatively large share of investment in the last years was directed towards the 'new' renewables solar and wind. The *Domestic Energy Policy* scenario leads to a comparatively stronger increase in hydro (77.8% of total generation mix), followed by biomass (10.4%) and wind (7.5%) and no visible increase in solar. This change reflects that the support for renewables in this scenario is assumed to be similar for hydro, wind, biomass, and solar, without consideration of the different economic profitability of these technologies. Finally, the *Preferential Trade Agreement* scenario does not lead to a shift in the generation mix compared to the base year because the tariff reduction for low carbon technologies for inputs to the electricity sector leads only to marginal cost advantages that are insufficient to trigger additional investment into renewable electricity generation.

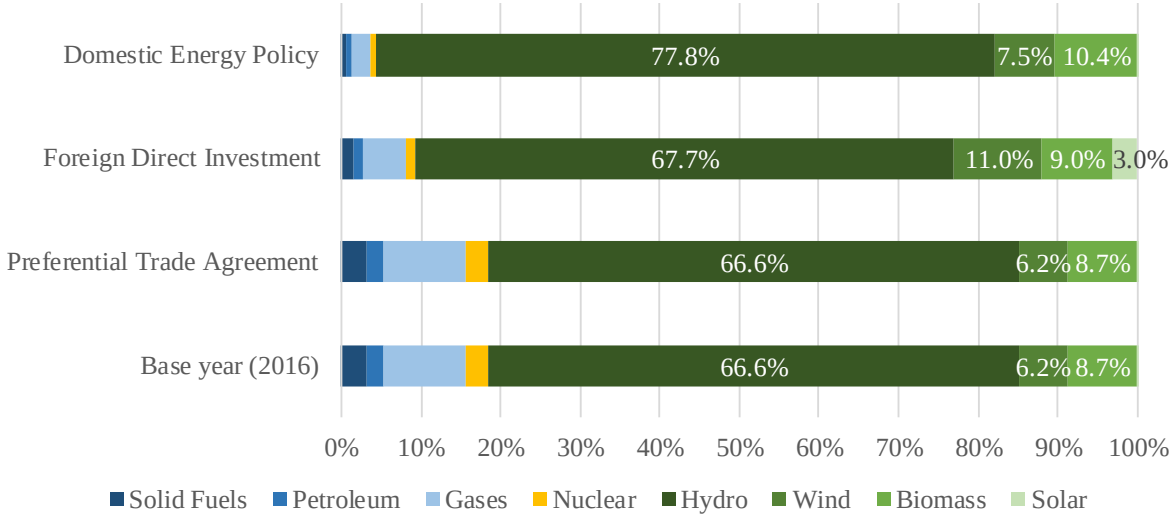


Figure 3: Electricity generation mix (share of average annual generation in kWh) in Brazil for the base year (EPE 2017a, 2017b), and the three policy scenarios

Since each of the policies is differently effective in increasing the shares of renewables in the electricity mix, the effects on GDP and CO_2 emissions are compared in relative terms, i.e., the effect is presented per 1% point increase in the share of the new renewables (wind, solar, and biomass) in the generation mix. Figure 4 therefore illustrates how the three policies affect GDP in Brazil, the European Union, and the Rest of the World. The *Foreign Direct Invstment* policy leads to a positive contribution to GDP in Brazil of 0.03% because European foreign investment generates economic activity in Brazil not just in the electricity sector but also in other sectors (agricultural crops, energy intensive industries such as iron and steel (I_S), chemicals (CRP); food products (MEG), metals (MET) and machinery (TEO)). Since this investment is no longer spent in Europe, European GDP is

negatively affected, but this effect is negligible (-0.003%) because the European GDP is a manifold of the Brazilian GDP. The *Domestic Energy Policy* scenario leads to a reduction in Brazilian GDP by 0.02%, even though the policy costs of renewable electricity support are financed out of additional revenues from fossil fuel taxes and therefore the costs for the electricity sector are comparatively small. However, the higher fossil fuel taxes lead to higher costs in other energy intensive sectors and in final demand, dampening sectoral output (most strongly in fossil fuel sectors, to a smaller degree also in agriculture, transport, in energy intensive industries like chemicals; and in service sectors). Due to international trade linkages, both policies lead also to slight negative effects on the Rest of the World because Brazilian imports decrease slightly in both scenarios. Since also Brazilian exports decline in the *Domestic Energy Policy* scenario, the effect on GDP in the Rest of the World is stronger than in the *Foreign Direct Investment* scenario. Again, the size of the effect of the *Preferential Trade Agreement* policy on Brazilian GDP, and also in the two other policy regions, is negligible.

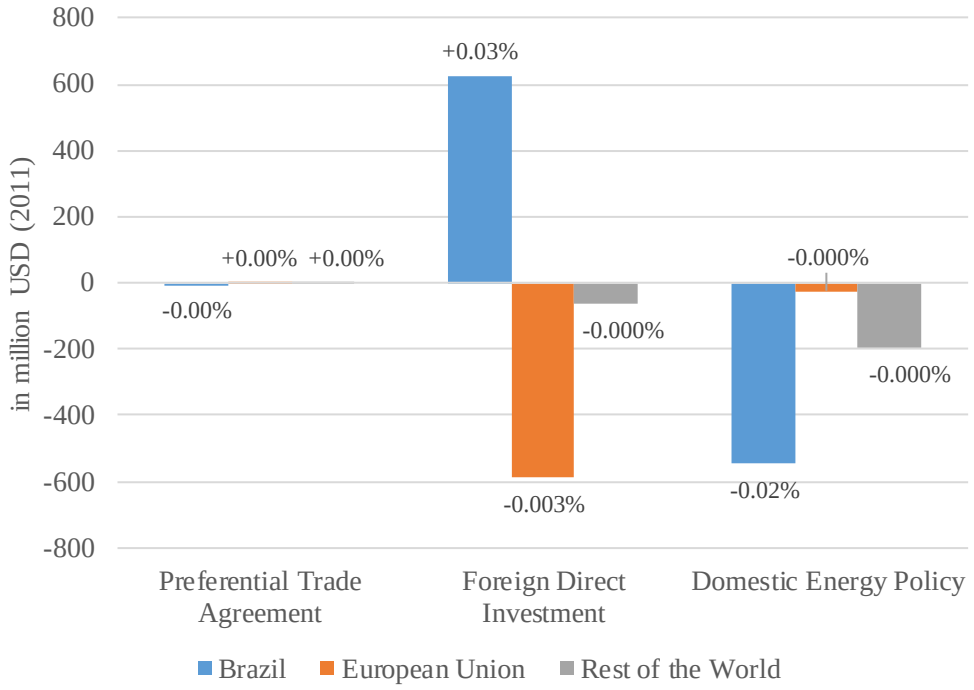


Figure 4: Normalized change in GDP (absolute change and % change, both relative to the base year) by policy region for the three policy scenarios.

Note: To make the effect size of the different policies comparable, GDP effects are normalized per 1%-point increase in the share of wind, solar, and biomass in the Brazilian electricity generation mix. Rest of the World is the aggregate of all other model regions except Brazil and EU.

Figure 5 illustrates how CO_2 emissions change in the three policy scenarios. The *Domestic Energy Policy* scenario is most effective in reducing emissions (by 1.86% per 1%-point increase in the share of wind, solar and biomass in the Brazilian generation mix), followed by the *Foreign Direct Investment* policy (decrease of 0.33% in CO_2 emissions per 1%-point increase in the share of wind, solar, and biomass). This is due to the fact that the *Foreign Direct Investment* policy affects emissions directly only in the electricity sector in Brazil; emissions in other industry and service sectors even increase slightly due to cheaper electricity. In contrast, the *Domestic Energy Policy* affects fossil fuel use also in all other sectors, leading to significant emission reductions in fossil fuel and transport sectors as well as by households. With this latter policy, the economy-wide reduction in CO_2

emissions is therefore contributed by 77% from the electricity sector and by 23% from all other sectors and households. None of the policies leads to emission increases in the European Union or in the Rest of the World; in the European Union, emissions are even marginally reduced by 0.004% (*Foreign Direct Investment* scenario) and by 0.003% (*Domestic Energy Policy* scenario) due to reduced economic activity (negative GDP effects in the European Union in both scenarios). The *Preferential Trade Agreement* policy has again no significant impact on CO_2 emissions as it is not effective in increasing the share of 'new' renewables in the Brazilian electricity generation mix.

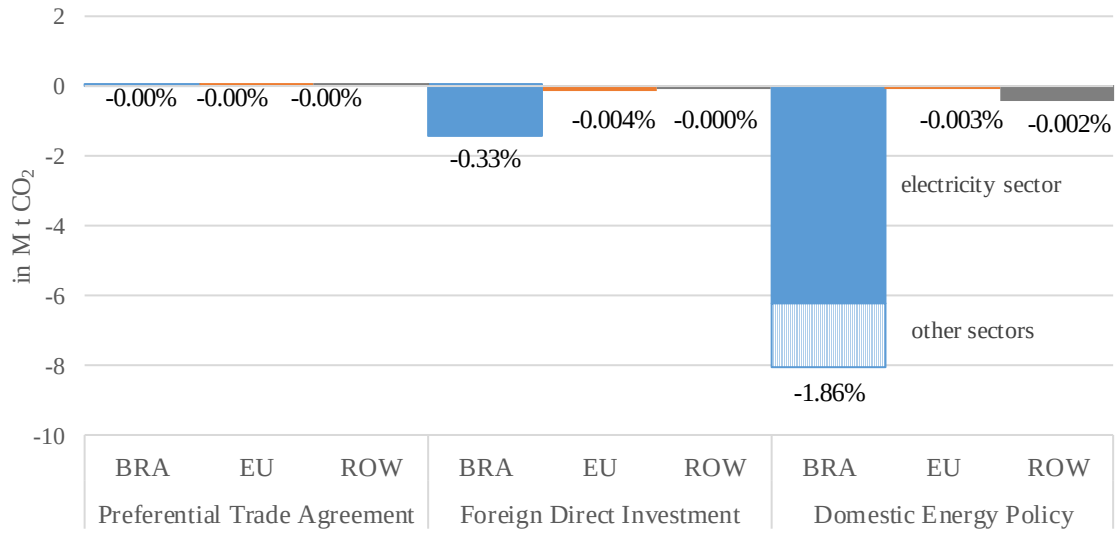


Figure 5: Normalized change in CO_2 emissions (absolute change and % change, both relative to the base year) by policy region for the three policy scenarios and decomposition of effect in Brazil into reduction within the electricity sector and in all other sectors and households.

Note: To make the effect size of the different policies comparable, GDP effects are normalized per 1%-point increase in the share of wind, solar, and biomass in the Brazilian electricity generation mix. Region abbreviations: BRA = Brazil, EU = European Union; ROW = Rest of the World (aggregate of all other model regions).

6. Discussion and conclusions

Preferential trade agreements with climate-related provisions have been suggested as alternative to New Market Mechanisms because they have potentially several advantages: the small number of parties increases the likelihood and speed of such an agreement; the possibility of even yearly negotiations provides much greater flexibility; and they can potentially not only make the achievement of NDCs in emerging economies more likely but may also lead to more ambitious targets in the upcoming UNFCCC global stocktake.

The present paper demonstrates, however, that preferential trade agreements need to have certain elements to effectively contribute to mitigation and lead to wider economic benefits. In line with Dong and Whalley (2011), we find that the removal of import tariffs on renewable energy technology (policy scenario *Preferential Trade* Agreement) is quite ineffective in scaling up the share of wind, solar, and biomass in Brazil. The reason for this result is twofold: first, the renewable energy technology is already today only subject to comparatively small tariff rates; and second, the cost contribution of these technologies to the unit costs in renewable electricity generation is comparatively small. Tariff reductions on renewable energy technology, as one type of environmental

goods and services, are therefore not a sufficient measure to reinforce NDCs in emerging countries but need to be combined with other measures.

One potential complementary measure to the removal of trade barriers on environmental goods and technologies is the support of FDI. In our model-based policy analysis, we find that FDI by the European Union in Brazil with a focus on renewable electricity generation is effective in both increasing the share of wind, solar, and biomass in the Brazilian generation mix and in reducing CO_2 emissions. Moreover, the FDI policy has a positive impact on the Brazilian economic performance (measured as % change in GDP). We therefore conclude that when a PTA is able to trigger substantial FDI flows, then a PTA can be an effective instrument to mitigation in emerging economies. In order to attract this required level of FDI into the renewable energy sector, PTAs should therefore be complemented with other policy instruments. Domestic policies such as fiscal measures[84], i.e., tax incentives, have proved to be effective instruments to attract investments in new renewables (Marques and Fuinhas 2012; Polzin et al. 2015; Wall et al. 2018). Other fiscal instrument that has shown effectiveness is the feed-in tariff (Verbruggen and Lauber 2012; Bolkesjo et al. 2014; Wall et al. 2018).

As a final policy simulation, we compared the two PTA elements to a domestic energy policy. Here the assumption was that fossil fuel taxes are raised (to levels similar to the rates in the USA or other Latin American countries) and that these tax revenues were used to subsidize renewable electricity generation from wind, solar, and biomass. There are two striking differences to the FDI policy case: first, the domestic energy policy is more than five times effective in mitigation as is the FDI policy case; second, the effect of the domestic energy policy on the Brazilian GDP is negative, due to higher oil prices which affect output negatively not only in the fossil fuel sectors (and here primarily the oil sector) but also in energy-intensive industrial sectors. While the domestic energy policy is therefore highly effective in terms of mitigation, there is a trade-off in terms of higher energy prices and reduced economic performance.

When looking at emission reductions, our model-based policy analysis for Brazil and the EU demonstrates that domestic energy policies clearly exert a bigger leverage on emission reductions within emerging economies like Brazil than preferential trade agreements (capable of generating FDI and not just removing import tariffs on renewable energy technologies) can do by themselves. But as domestic energy policies may have negative economic consequences, preferential trade agreements capable of generating FDI can buffer this side-effect and thereby increase the political acceptability of ambitious NDC targets in the electricity sector. In turn, domestic energy and climate policies, such as support for renewables, can also attract FDI flows, and ensure that preferential trade agreements unfold their contribution to mitigation and economic performance. Ultimately, domestic policies and preferential trade agreements could form therefore an effective policy package that serves both needs of mitigation and economic performance.

[84] Wall et al. (2018) found that carbon pricing instruments are also effective in attracting renewable energy FDI. In particular, emission trading schemes showed more effectiveness in non-OECD countries, while carbon taxation in OECD countries.

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Appendix

We extend the model and scenario description of section 4 with further technical details in this appendix. Table A-1 and Table A-2 depict the regional and sectoral aggregates used in the model, aggregated from the regions and sectors provided in the GTAP database.

On a sectoral level, we further disaggregate the electricity sector for Brazil and Europe. In the model we nest the different electricity technologies with in one electricity sector (see Figure A-1). Each technology consists of capital, labor and sectoral intermediate inputs. Fossil fuel technologies further need technology specific fuel inputs causing CO_2 emissions from their combustion. We assume fixed input shares within each technology by assigning a zero elasticity of substitution for all electricity technologies. A substitution between the different technologies is, however, allowed by the elasticity top, for which we assign a value of 10. To supply a unit of electricity we further nest the transmission and distribution sector (consisting again of capital, labor and sectoral intermediate inputs) with a constant share to the electricity generation from the different technologies.

Figure A-1: Nesting structure of the disaggregated electricity sector

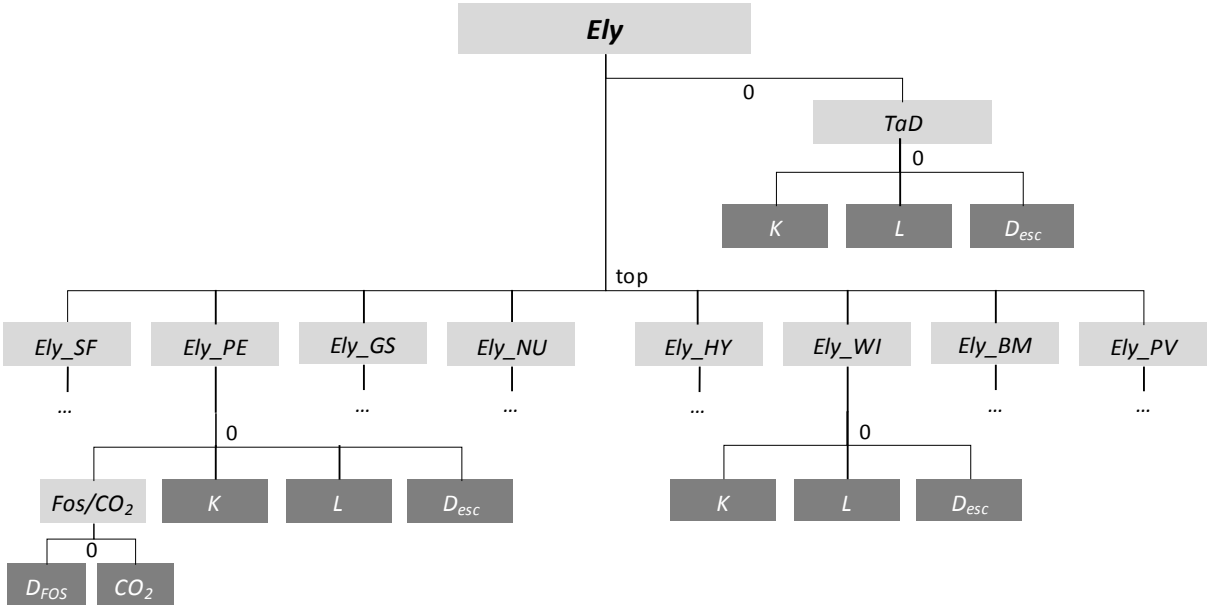


Table A-1: Sectoral aggregation in the CGE model from the GTAP database (Aguiar et al. 2016)

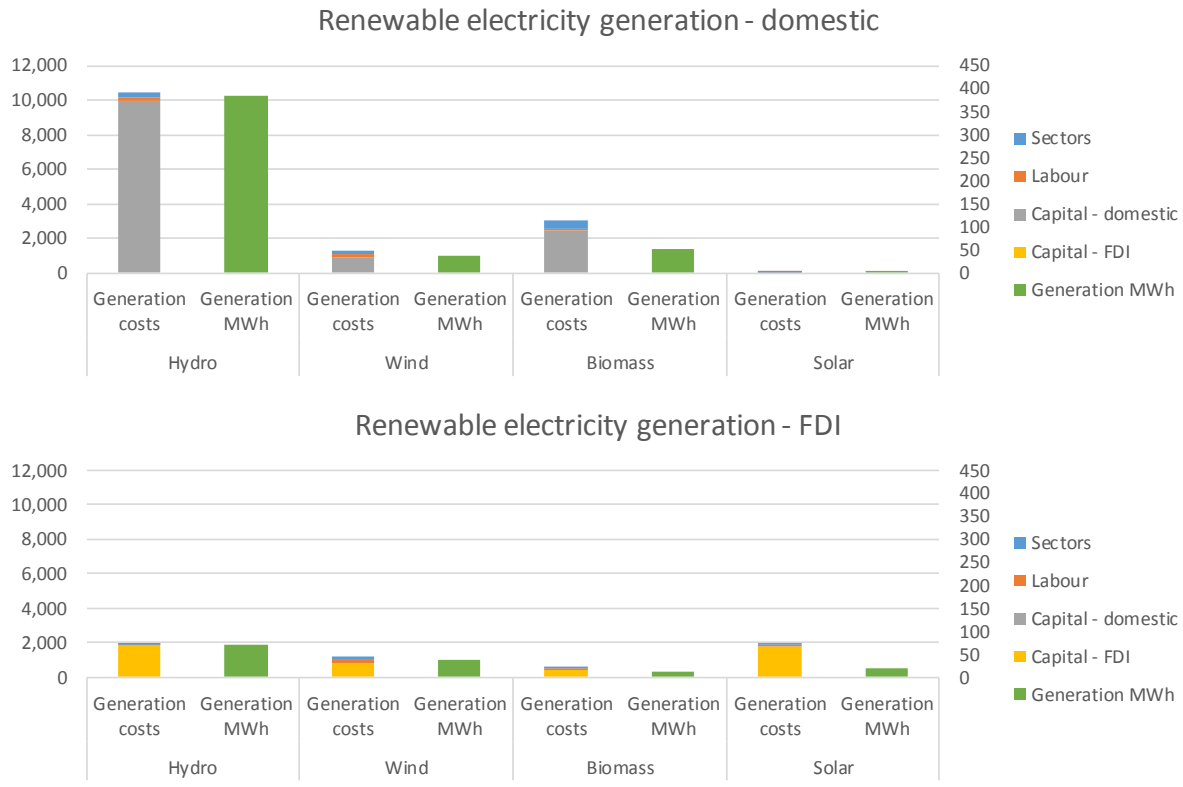
Model sectoral aggregate		Aggregated GTAP sectors (code and sector)					
AVEG	*Agricultural crops*	PDR	Paddy rice	WHT	Wheat	GRO	Cereal grains nec
		V_F	Vegetables, fruit, nuts	PFB	Plant-based fibers	OCR	Crops nec
OILS	*Oil seeds*	OSD	Oil seeds				
SUGA	*Sugar plants*	C_B	Sugar cane, sugar beet				
AMEA	*Agriculture, animalistic*	CTL	Bovine cattle, sheep and goats, horses	OAP	Animal products nec	RMK	Raw milk
		WOL	Wool, silk-worm cocoons				
EXT	*Extraction*	FRS	Forestry	FSH	Fishing	OMN	Minerals nec
COA	*Coal*	COA	Coal				
OIL	*Oil*	OIL	Oil				
GAS	*Gas*	GAS	Gas	GDT	Gas manufacture, distribution		
MEG	*Food products*	OMT	Meat products nec	CMT	Bovine meat products	VOL	Vegetable oils and fats
		MIL	Dairy products	PCR	Processed rice	SGR	Sugar
		OFD	Food products nec	B_T	Beverages and tobacco products		
TEX	*Textiles*	TEX	Textiles	WAP	Wearing apparel	LEA	Leather products
WOOP	*Wood and paper products*	LUM	Wood products	PPP	Paper products, publishing		
P_C	*Petroleum, coal products*	P_C	Petroleum, coal products				
CRP	*Chemicals*	CRP	Chemical, rubber, plastic products				
NMM	*Mineral products*	NMM	Mineral products nec				
I_S	*Iron and steel*	I_S	Ferrous metals				
MET	*Metals*	NFM	Metals nec	FMP	Metal products		
MVE	*Motor vehicles and parts*	MVH	Motor vehicles and parts	OTN	Transport equipment		
TEO	*Machinery*	OME	Machinery and equipment				
TEC	*Electronic equipment*	ELE	Electronic equipment	OMF	Manufactures nec		
ELY	*Electricity*	ELY	Electricity				
ELY_SF	*Solid Fuels*						
ELY_PE	*Petroleum*						
ELY_GS	*Gases*						
ELY_NU	*Nuclear*						
ELY_HY	*Hydro*						
ELY_WI	*Wind*						
ELY_BM	*Biomass*						
ELY_PV	*Solar*						
TaD	*Transmission and distribution*						
CNS	*Construction*	CNS	Construction				
TRD	*Trade*	TRD	Trade				
SERV	*Services*	CMN	Communication	OFI	Financial services nec	ISR	Insurance
		OBS	Business services nec	ROS	Recreational and other .	DWE	Dwellings
OSG	*Government services*	OSG	Public Administration, Defense, Education,	WTR	Water		
TRN	*Transport*	WTP	Water transport	OTP	Transport nec	ATP	Air transport

Table A-2: Regional aggregation in the CGE model from the GTAP database (Aguiar et al. 2016)

Model regional aggregate		Aggregated GTAP regions (code and region)					
BRA	*Brazil*	BRA	Brazil				
EUN	*European Union*	AUT	Austria	BEL	Belgium	CYP	Cyprus
		CZE	Czech Republic	DNK	Denmark	EST	Estonia
		FIN	Finland	FRA	France	DEU	Germany
		GRC	Greece	HUN	Hungary	IRL	Ireland
		ITA	Italy	LVA	Latvia	LTU	Lithuania
		LUX	Luxembourg	MLT	Malta	NLD	Netherlands
		POL	Poland	PRT	Portugal	SVK	Slovakia
		SVN	Slovenia	ESP	Spain	SWE	Sweden
		GBR	United Kingdom	CHE	Switzerland	NOR	Norway
		XEF	Rest of EFTA	BGR	Bulgaria	HRV	Croatia
		ROU	Romania				
USA	*United States of America*	USA	United States of				
CHN	*China*	CHN	China				
MER	*Mercosur*	ARG	Argentina	PRY	Paraguay	URY	Uruguay
ROW	*Rest of the World*	CAN	Canada	XNA	Rest of North	ALB	Albania
		BLR	Belarus	RUS	Russian	UKR	Ukraine
		XEE	Rest of Eastern	XER	Rest of Europe	TUR	Turkey
		XTW	Rest of the World				
LAM	*Latin America*	MEX	Mexico	BOL	Bolivia	CHL	Chile
		COL	Colombia	PER	Peru	XSM	Rest of South America
		CRI	Costa Rica	GTM	Guatemala	HND	Honduras
		NIC	Nicaragua	PAN	Panama	SLV	El Salvador
		XCA	Rest of Central	DOM	Dominican	JAM	Jamaica
		PRI	Puerto Rico	XCB	Caribbean	TTO	Trinidad and Tobago
OGA	*Oil/Gas exporting countries*	ECU	Ecuador	VEN	Venezuela	BHR	Bahrain
		IRN	Iran	JOR	Jordan	KWT	Kuwait
		OMA	Oman	QAT	Qatar	SAU	Saudi Arabia
		ARE	United Arab	XWS	Rest of Western	EGY	Egypt
		MAR	Morocco	TUN	Tunisia	XNF	Rest of North Africa
		NGA	Nigeria	XAC	South Central		
ASO	*Asia and Oceania*	AUS	Australia	NZL	New Zealand	XOC	Rest of Oceania
		HKG	Hong Kong	JPN	Japan	KOR	Korea Republic of
		MNG	Mongolia	TWN	Taiwan	XEA	Rest of East Asia
		BRN	Brunei Darussalam	KHM	Cambodia	IDN	Indonesia
		LAO	Lao PDR	MYS	Malaysia	PHL	Philippines
		SGP	Singapore	THA	Thailand	VNM	Viet Nam
		XSE	Rest of Southeast	BGD	Bangladesh	IND	India
		NPL	Nepal	PAK	Pakistan	LKA	Sri Lanka
		XSA	Rest of South Asia	KAZ	Kazakhstan	KGZ	Kyrgyzstan
		XSU	Rest of Former	ARM	Armenia	AZE	Azerbaijan
		GEO	Georgia	ISA	Israel		
AFR	*Africa*	BEN	Benin	BFA	Burkina Faso	CMR	Cameroon
		CIV	Cote d'Ivoire	GHA	Ghana	GIN	Guinea
		SEN	Senegal	TGO	Togo	XWF	Rest of Western Africa
		XCF	Central Africa	ETH	Ethiopia	KEN	Kenya
		MDG	Madagascar	MWI	Malawi	MUS	Mauritius
		MOZ	Mozambique	RWA	Rwanda	TZA	Tanzania
		UGA	Uganda	ZMB	Zambia	ZWE	Zimbabwe
		XEC	Rest of Eastern	BWA	Botswana	NAM	Namibia
		ZAF	South Africa	XSC	Rest of South		

For the modelling of the tariff reduction for renewable electricity technology (*Preferential Trade Agreement* scenario) in the CGE model, we remove the tariff on imports of sectoral outputs of Machinery and equipment (TEO) and Electronic equipment (TEC) from Europe, that are used in the renewable electricity sectors of Brazil. In the *Foreign Direct Investment* scenario, we assume the increase of new renewables to reach a share of 23% in the electricity generation mix of Brazil. We assign sector-specific domestic capital as input in each electricity technology and additional European capital input. The cost structure with domestic capital inputs and FDI as well as average annual generation for the different renewable technologies are given in Figure A-2. Annual FDI in renewables which is required to meet the NDC target sums up to 4.9 billion USD, which is quite substantial, compared to 11 billion USD of total average annual greenfield investments from the EU to Brazil in the period from 2006 to 2015 (APEX-BRASIL 2017). We further assume an increased capital effectiveness of European FDI compared to domestic capital inputs, implemented as less FDI input necessary to produce one unit of electricity output. The reduced FDI inputs for the different technologies are assumed to be 80% for hydro, 90% for biomass, and 20% for solar.

Figure A-2: Renewable electricity generation and cost from domestic and foreign direct investment.



5. Results and conclusions

In this section, main results and conclusions of this dissertation are discussed. First, the most relevant findings of each paper are linked to its respective research question, so that the individual contribution of each paper becomes clear. Then, key findings are linked across papers in order to drawn a general conclusion. Finally, conclusions, limitations and directions for future research of this dissertation are discussed.

5.1. Key findings

As presented in section 1, the overall objective of this dissertation is to investigate the economic impacts of climate mechanisms in developing countries. From this overall objective, three specific objectives are framed; each of them represents one research paper respectively (Table 5). A synthesis of the main results by paper is provided in the following.

Table 5: Research objectives and papers

Research objective	Paper
To test empirically for the impacts of CDM investments on sustainable development across Brazilian municipalities, with a focus on income and poverty indicators	1
To complement the previous research objective with an assessment of cross-sectoral effects in employment in Brazilian municipalities with CDM projects	2
To assess the impacts of a preferential trade agreement with climate-related provisions between Brazil and the European Union on emission reductions and economic performance in Brazil;	3

Paper 1 (research objective 1) analyzes to which extent CDM investments in Brazilian municipalities have led to sustainable development benefits. Here, I focus on identifying impacts on development indexes and poverty indicators. Positive and significant differences have been identified for the overall FMDI development index in municipalities with CDM projects irrespective of project type. This finding might be interpreted carefully as this compound indicator includes variables not expected to be significantly affected by the CDM. Moreover, CDM projects have improved income and labor FMDI indicators except for hydro projects. This might be explained by the differences in factor demand requirements by project type: hydro tends to be more capital intensive, while biomass, landfill-gas and methane avoidance projects are more labor intensive. Only hydro projects are found to have contributed to reduce poverty and inequality for the period analyzed. These findings are in line with ex-ante studies based on the PDDs that question the contribution of CDM projects to poverty alleviation (Sirohi 2007; Subbarao and Lloyd 2011; Crowe 2013).

Paper 2 (research objective 2) assesses cross-sectoral effects in employment over time across Brazilian municipalities. Results show that CDM projects had mixed and transitory effects on sectoral employment. Regardless of project type, these impacts are found to be small and temporary, i.e., they took place immediately or within the first, second or third year after the registration of the project, which correspond to the construction phase and early years of project's operation. By project type, municipalities with hydro projects show a positive impact on commerce, a negative effect on agricultural employment, an overshooting effect in industrial employment, but no effects on the service and construction employment. In the case of municipalities with CDM methane avoidance projects, a positive impact is found on employment in commerce, service and construction; a negative effect on employment in agriculture, while no effect on industry employment. Revenues from Certified Emission Reductions (CER) seem to have no or a very small positive impact on sectoral employment, and no significant impact is found for the CER price fall in 2012.

Paper 3 (research objective 3) quantifies the impacts of a preferential trade agreement with climate-related provisions between Brazil and the European Union on emission reductions and economic performance. In particular, it looks into three scenarios: (i) removal of import tariffs on renewable energy equipment; (ii) promotion of climate-related FDI and (iii) domestic energy policy that combines fossil-fuel taxes and renewable subsidies. Main findings show that the environmental effectiveness of a preferential trade agreement targeting renewable electricity generation strongly depends on its design as the sole removal of import tariffs on renewable energy technology is quite ineffective in scaling up new renewables (wind, solar, biomass) in Brazil. In contrast, a trade agreement promoting climate FDI flows is an effective alternative in increasing the share in new renewables and reducing CO_2 emissions, while positively affecting economic performance in Brazil. When comparing the two previous approaches to a domestic energy policy, although this last policy is more mitigation effective than the trade agreement promoting renewable energy FDI, there is a trade-off between emission reductions and economic performance. A policy combination of a trade arrangements supporting climate FDI and fiscal measures may work as effective policy package to avoid conflicts between goals.

5.2. Conclusions, limitations and future research

Previous research on the impacts of climate instruments on sustainable development, i.e., CDM, has applied qualitative methods using data provided by project developers. Findings by these studies reflect only potential and thus not real impacts. To address this gap, part of this dissertation focuses on quantifying effects using empirical data provided by official statistical sources in Brazil, the country case study of this dissertation. This effort to quantify the impacts of CDM projects on sustainable development represents an important contribution to the literature on the effects of climate instruments in force in host countries.

Given the flaws of CDM in delivering sustained development benefits as demonstrated in Paper 1 and Paper 2, to complement this research, in Paper 3 I proposed to explore the effects of trade measures through the assessment of a preferential trade agreement with climate-related provision as a candidate for a NMM in the post-Kyoto era. Even though this approach does not quantify impacts on sustainable development directly, it explores a potential trade-off between emission reductions and economic performance. A combination of instruments, i.e., a preferential trade agreement supporting

renewable energy FDI plus domestic fiscal measures, could work as effective policy package to avoid conflicts between these two objectives.

The three articles that constitute this dissertation complement each other as they examine the impacts of a climate instrument currently in force in host countries such as the CDM (Paper 1 and Paper 2), while exploring effects of an alternative mechanism that uses trade arrangements to increase incentives for achieving mitigation without compromising economic performance in host countries (Paper 3). As emerging economies still require support from developed economies, the implications of a new instrument in the form of a trade agreement with climate goals between Brazil and the European Union are investigated.

To understand the scope and significance of climate mechanisms, ex-post assessments are necessary. Any further improvements as well as future design of new instruments demand quantification of the impacts of the mechanisms already in force such as the CDM. Lessons provided by ex-post assessments contribute in the formulation of a NMM, which may attempt to keep the twofold objective of this Kyoto's flexibility mechanism in the context of the Paris Agreement. In the particular case of the CDM, although the quantification of impacts is essential, it is not exempt from challenges. The absence of international standards for the assessment of sustainable development impacts of CDM projects as well as the missing obligation for the host countries to monitor and verify project's achievements complicate this task. This research attempted to find and select indicators able to represent (to some extent) some dimensions of what a *sustainable development* strategy might target as well as to find data able to capture these effects. As quantification is a core tool for policy design, future instruments targeting sustainable development goals should consider in their design the development and standardization of indicators to capture impacts accurately. Moreover, as the Paris Agreement highlights an intrinsic relationship between mitigation and sustainable development, these indicators should also be aligned with the Sustainable Development Goals. The standardization of indicators would also facilitate country comparisons. Similarly, monitoring, verification and reporting of impacts should also be part of this package (Olsen et al. 2017).Regarding main limitations of this dissertation, impacts environmental quality, which is a very relevant dimension of any sustainable development strategy, have not been assessed due to data constraints. Regarding the ability of the selected indicators to capture the CDM effects, it can be argued that some indicators may represent more accurately the reality of the Brazilian municipalities than others. For instance, this is the case when comparing development indexes (e.g. the FMDI vs. the MHDI) whose composition differs as well as data sources. With respect to other selected indicators such as poverty and the Theil index, it can be argued that effects on these variables could be even more long-term (except for hydro) as it may take a while until improved living standards at the local level could be observed. Again, the identification of operational indicators as well as exploration of impacts under several time horizons may help to deal with issues.

Regarding impacts over time, as they could take place at different moments, quantification may require to distinguish them according to several time horizons (i.e., immediate, short, medium and long-term impacts) to have a complete picture of the dynamics of these effects. To address this gap, this dissertation estimated short and long-run effects of CDM projects on specific indicators, identifying short-term effects on employment generation, long-run effects on local economic performance, while no long-run effects on poverty and inequality (except for hydro projects). More longitudinal research is still needed that looks into the development of impacts over time by covering

a broader range of indicators and dimensions of a sustainable development strategy, analyzing them under different temporal horizons as well as testing for durability of these effects.

When analyzing the impacts of CDM projects on local sustainable development, it is necessary to take into account that the sole implementation may not lead automatically to benefits[85]. Although enhanced energy access has demonstrated to provide communities with several benefits (Bonan et al. 2016), for example, improvements in household income and more dynamic labor markets[86], findings are still inconclusive due to methodological challenges to elucidate causal-link effects (Alloisio et al. 2017). The causality chain may involve high levels of complexity due to the interactions among socio-economic variables and sectors at the local level; moreover, potential negative effects might threaten to offset positive gains on welfare (ERIA 2008).

In the particular case of employment generation, effects on this variable will depend on not only technology type (e.g., labor intensive vs. capital intensive technologies), but also on project's stage, local resource endowment as well as local socio-economic and cultural conditions. Thus, understanding the local situation and how the local economic sectors are linked, it is essential to grasp how a renewable energy project could contribute to this socio-economic system. This is a pre-condition to take advantage of local potentialities and foresee impacts. Future research may attempt to deeper disentangle the contribution of renewable energy projects to sustainable development to enhance our understanding on the causality chain and their potential effects.

Taken together, the results of these articles suggest that lessons from previous climate instruments such as the CDM can be used for future proposals on a NMM that aims to fulfil the two-fold objective (i.e., achievements in emission reductions without compromising economic performance). As discussed in Paper 3, a combination of instruments (i.e., FDI and fiscal measures) could work as effective policy package to avoid conflicts between objectives. While preferential trade agreements capable of generating FDI may buffer the side-effect of the domestic energy policy, domestic fiscal measures supporting investments in renewables can also attract FDI flows, and ensure the achievement this two-fold target.

Future work may attempt to explicitly incorporate sustainable development goals in CGE modelling for the assessment of climate mitigation side effects on poverty and inequality. Moreover, as sustainable development encompasses several dimensions (i.e., environmental, economic and social), which may be closely inter-connected, model extensions could allow for a systematic quantitative analysis of potential trade-offs.

[85] Although most literature are focused on detangling the causality effects of renewable energy projects on sustainable development, this can be extended to other categories such as waste management projects.

[86] To give an example, local improved energy access may attract firms that will demand labor. This may in turn contribute to improve household's income as well as stimulate local labor markets.

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