Analysis

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 seldomly 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.

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” (United Nations, 2015). Job creation is one of the benefits most commonly claimed by different types of CDM projects (United Nations Framework Convention on Climate Change, 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 CO2 emission reductions are verified by the UNFCCC and generate revenues to project developers in the form of Certified Emission Reductions’ (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 projects and hosted the first project worldwide in 2004. 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) (United Nations Environment Programme (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 Project, 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, 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 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, 2003).

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 Project, 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 Project, 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 but also contractive effects that could affect energy-intensive sectors such as

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3 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).

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2 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.
manufacturing (Hillebrand et al., 2006). This contractual 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, 2011). The net total result on local employment, which is the sum of direct, indirect and induced employment, will depend on how much the contractual 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; 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 (2019) estimated impacts of CDM across Brazilian municipalities and identified a positive effect on labor and income indexes 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 Iguaçu. As of 2015, there are totally 338 CDM projects registered in the Executive Board (United Nations Environment Programme (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 (mthane 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 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.

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 2012.4 These income-labor indicators are aggregated indexes at the municipal level; no sectoral effects were estimated.

5 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).
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 after 2012 are eligible if they were hosted by Least Developed Countries (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., 2015). 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 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, 2016) from the Annual Report on Social Information (RAIS).

Regarding explanatory variables in the model, we use a proxy variable for CDM which is a dichotomous variable that assigns “1” to those municipalities with a CDM project at time \( t \); this starts from project’s registration 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. Two category of projects were analyzed: a) hydro (renewable energy sector), and b) methane avoidance (waste handling and disposal sector). 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: 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).

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) as well as demographic indicators such as population growth at the municipal

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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: United Nations Environment Programme (UNEP) (2015).

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9 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.

10 From the 425 municipalities with CDM investments, 349 municipalities had only one project.

11 Other project’s types such as wind, biomass and landfill gas were not included in the analysis due to sample issues.

12 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 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).
level. All economic and demographic data come from the Brazilian Institute of Geography and Statistics (IBGE, 2014, 2015). Some descriptive statistics are displayed in Table 3. Further details on employment and GDP growth at the federal state level in municipalities with a CDM project that generated CER credits at time $t$ is an error term.

$$y_{it} = \alpha y_{i,t-1} + \beta x_{it} + \mu_i + \epsilon_t$$ (1)

The unobserved individual-specific effects are correlated with the autocorregressive 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 individual countries, 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 statistics. 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 a CDM project at time $t$. Table 4 describes the 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; $\mu_i$ represents unobserved individual-specific effects, while $\epsilon_t$ is an error term.

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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).
### 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:           | $-0.04$                      | 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       | 0.13***                     | 0.002**                      | (Municipality)                   | 0.011**                     | (Municipality)                | 0.002                        |
|                       | (0.04)                      | (0.001)                      | (Municipality)                   | (0.004)                     | (Municipality)                | (0.002)                      |
| Population growth      | $-0.28^{**}$                | $-0.007$                     | 0.04                             | 0.007                       | 0.02                          | 0.02                         |
|                       | (0.13)                      | (0.03)                       | (0.04)                           | (0.02)                      | (0.05)                        | (0.02)                       |
| Time dummy:           | $-0.04$                      | 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                         |

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 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                        | $-0.004$                         | 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                       | 0.003                         | $-0.007$                    |
|                       | (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                         | $-0.003$                    |
|                       | (0.02)                      | (0.005)                      | (0.009)                          | (0.004)                     | (0.006)                       | (0.003)                      |
| Total GDP growth       | 0.13***                     | 0.004                        | (Federate State)                 | 0.023**                     | (Federate State)              | 0.012                        |
|                       | (0.04)                      | (0.005)                      | (Federate State)                 | (0.008)                     | (Federate State)              | (0.002)                      |
| Population growth      | $-0.28^{**}$                | 0.05                         | $-0.09^{*}$                      | $-0.04$                     | $-0.02$                       | $-0.02$                     |
|                       | (0.13)                      | (0.034)                      | (0.059)                          | (0.031)                     | (0.03)                        | (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.
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 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 for the CER proxy and the time dummy for 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 (United Nations Framework Convention on Climate Change, 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.

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, consequentely, 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.

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, 2010). 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 |
|---------------|----------------|----------------|-------|---------|
| 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                      | 0.06                   |
|                       | (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: CER crisis| 0.07                 | 0.10                    | −0.02                      | 0.03                   |
|                       | (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*                |
| CDM                   | −0.03                | 0.02                    | −0.05                     | −0.007                |
| CDM Lag 1             | −0.005               | −0.007                  | −0.008                    | 0.003                 |
| CDM Lag 2             | −0.03                | −0.005                  | 0.004                     | −0.06**               |
| CDM Lag 3             | 0.04*                | 0.02                    | 0.13*                     | 0.09***               |
| CER                   | 0.02                 | −0.03                   | −0.05                     | 0.004                 |
| Total GDP growth      | 1.07***              |                         |                           |                       |
| GDP industry growth   |                      | 0.54***                 |                           |                       |
| GDP agriculture growth|                      |                         | 1.19***                   |                       |
| Population growth     | 0.27 *               | −0.18                   | 0.03                      | 0.17                  |
| 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**                      |
| CDM                   | −0.06                       | −0.002                       | −0.016**                        | 0.004                        | −0.001                           | 0.013***                    |
| CER                   | −0.05                       | 0.002                        | 0.001                           | 0.006                        | 0.007                            | −0.008                      |
| Time dummy:           |                             |                              |                                 |                              |                                  |                             |
| CER crisis            | −0.04                       | 0.002                        | 0.006                           | 0.000                        | −0.008                           | −0.002                      |
| Total GDP growth      | 0.13**                      | (0.08)                       | 0.002                           | (0.004)                      | 0.011***                         | (0.003)                     |
| GDP industry growth   | 0.002*                      | (0.004)                      | 0.011***                        | (0.003)                      |                                  |                             |
| GDP agriculture growth| 0.005                       | (0.002)                      |                                  |                               |                                  |                             |
| GDP services growth   | 0.017**                     | (0.008)                      | −0.006**                        | (0.003)                      |                                  |                             |

(continued on next page)
Table A.4 (continued)

| 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 |
|-----------------------|-----------------------------|-------------------------------|----------------------------------|-------------------------------|----------------------------------|-------------------------------|
| 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: CER crisis | −0.025                     | 0.002                         | 0.003                            | −0.004                        | −0.002                           | −0.002                        |
|                       | (0.016)                     | (0.005)                       | (0.008)                          | (0.004)                       | (0.004)                          | (0.002)                       |
| Total GDP growth (Federate State) | 0.12*                      | 0.01                          | 0.023**                          | 0.023**                       | 0.011                            | 0.03*                         |
|                       | (0.04)                      | (0.02)                        | (0.008)                          | (0.003)                       | (0.01)                           | (0.01)                        |
| GDP industry growth   |                             |                               | 0.01                            |                               | 0.023**                          |                               |
| (Federate State)      |                             |                               | (0.002)                          |                               | (0.001)                          |                               |
| GDP agriculture growth|                             |                               | 0.011                           |                               | 0.023**                          |                               |
| (Federate State)      |                             |                               | (0.008)                          |                               | (0.003)                          |                               |
| GDP services growth   |                             |                               |                                 | 0.04*                         | 0.03*                            |                               |
| (Federate State)      |                             |                               |                                 | (0.03)                        | (0.01)                           |                               |
| Population growth     | −0.32***                    | 0.03                          | −0.08*                           | −0.07                         | −0.005                           | −0.02                         |
| (Municipality)        | (0.12)                      | (0.03)                        | (0.05)                           | (0.03)                        | (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

Fig. 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.
Fig. 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.
