Substituting fossil energy sources: the role of the climate funds and effects on the economic growth

Cafora, Alfonso and Romano, Antonio Angelo and Ronghi, Monica and Giuseppe, Scandurra

Department of Management Studies and Quantitative Methods, University of Naples "Parthenope" - via Generale Parisi, 13 - Naples (Italy)- I - 80132

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Alfonso Carfora (corresponding author)
Department of Management Studies and Quantitative Methods, University of Naples "Parthenope" - via Generale Parisi, 13 - Naples (Italy)- I - 80132
E-mail: alfonso.carfora@uniparthenope.it

Antonio A. Romano
Department of Management Studies and Quantitative Methods, University of Naples "Parthenope" - via Generale Parisi, 13 - Naples (Italy)- I - 80132
Tel.: +39-81-5474565 Fax: +39-81-5474904
E-mail: antonio.romano@uniparthenope.it

Giuseppe Scandurra
Department of Management Studies and Quantitative Methods, University of Naples "Parthenope" - via Generale Parisi, 13 - Naples (Italy)- I - 80132
Tel.: +39-81-5474922 Fax: +39-81-5474904
E-mail: giuseppe.scandurra@uniparthenope.it

Monica Ronghi
Department of Management Studies and Quantitative Methods, University of Naples "Parthenope" - via Generale Parisi, 13 - Naples (Italy)- I - 80132
E-mail: monica.ronghi@uniparthenope.it

Abstract

The Green Climate Fund (GCF) is a fund within the framework of the UNFCCC founded as a mechanism to assist developing countries in adaptation and mitigation practices to counter climate change. In this paper, we analyze the flow of funds among countries and investigate, through a counterfactual analysis, their effectiveness. The results show that as result of the receipt of the funds, countries reduced their GHG emission and have been incentivized in the replacement of fossil sources with renewable sources. Finally, also a leverage effect of the funds for economic development of the recipient countries comes into the light.

Keywords: Renewable and non-renewable energy sources; counterfactual analysis; economic growth; climate finance

JEL Classifications: C21, C54, O44, 047.

1. Introduction

During the 15th Conference of the Parties (COP15) held in December 2009 in Copenhagen, developed countries pledged to provide new and additional resources to combat climate change, approaching USD 30 billion for the 2010-2012 period, with balanced allocation between mitigation and adaptation. This collective commitment has come to be known as 'fast-start finance' and prefigures the institution of the Green Climate Fund (GCF) established by the 194 countries that are party to the UN Framework Convention on Climate Change in 2010, with a mission to support a paradigm shift in the global response to climate change. It allocates its resources to low-emissions and climate-resilient projects and programs in developing countries. The Fund pays particular attention to the needs of societies that are highly vulnerable to the effects of climate change, in particular Least Developed Countries (LDCs), Small Island Developing States (SIDS), and African States. These funds can be considered a preliminary version of the funding mechanism provided during the 21st COP in Paris, in which countries acted based on the goal of keeping the temperature increase on our planet below 2°C to reduce the concentration of carbon dioxide in the atmosphere, which reached the symbolic and significant milestone of 400 parts per million for the first time in 2015 and surged again to new records in 2016 (W.M.O., 2016).

The provisions of these financial instruments entail that donor governments distribute funds to recipient developing countries to finance concrete adaptation projects and programs to reduce the adverse effects of climate change that communities, countries and sectors are facing. Global climate finance architecture is complex: there are, in fact, a growing number of recipient countries that have established national climate change funds and that receive funding from multiple developed countries. A critical issue is the transparency of the implementation status of climate finance initiatives. Moreover, the proliferation of climate finance mechanisms increases the challenges of coordinating and accessing finance. In this context, the monitoring of countries' emissions to evaluate their progress toward reduction goals assumes an important meaning regarding the effectiveness of the policy of the climate funds.

Climate finance has been explored previously. Ellis et al. (2013) explore how different communities view climate finance effectiveness, the policies or institutional pre-conditions that facilitate effectiveness, and how effectiveness is currently monitored and evaluated. Bird et al. (2013) describe an approach to measuring the effectiveness of the national systems that support climate finance delivery. They assess three interlinked elements of government administration: the policy environment, which supports climate change expenditures; the institutional architecture, which determines the relevant roles and responsibilities; and the public financial system, through which climate change-related expenditures are channeled. The OECD, in collaboration with Climate Policy Initiatives (2015), provided a status check on the level of climate finance mobilized by developed countries in 2013 and 2014.

International cooperation on finance has the potential to help countries manage such tradeoffs and create new incentives for low-carbon development. Climate finance can support policies that can build resilience against the threats posed by climate change (Nakhooda and Norman, 2014).

In a recent paper, Carfora et al. (2017) find that funds directed to "fast-start finance" meet the requirements of ensuring the reduction in GHG and promoting the sustainable development of developing countries. To improve the effectiveness of climate funds, they suggest redesigning aid schemes not only to combat climate change but also to promote resilience to extreme events and to reduce dependence on preferential channels with developed countries.

Despite the relevance of the topic, the effectiveness of the distribution of climate funds and how these funds can mitigate the impact of anthropogenic activities have not been previously explored.

In this paper, we analyze the flow of funds among countries and conduct a counterfactual analysis to respond to the main research questions of the paper: i) have the recipient countries achieved the objectives of GHG emission reduction for which the funds were granted? ii) Are these funds useful for the countries in incentivizing the replacement of fossil sources with renewable sources? iii) Is there a leverage effect for economic development? Moreover, for each question, if the response is positive, we want to quantify these effects, making a comparison with the similar counterparts represented by non-recipient countries. To achieve our aims, we employ propensity score matching (PSM) analysis on a large dataset of 149[1] countries that includes countries that have received funds in 2010 (treated – 83 counties) and those that have not received funds (untreated – 66 countries). Propensity score matching (PSM) is a statistical method that permits the construction of a probabilistic match among units that have participated in a treatment (treated) and units that have not participated (untreated), utilizing characteristics that are common to both groups (Rosenbaum and Rubin, 1983). The results can be useful in determining the effectiveness of the climate mechanism and testing whether they are useful in promoting RES generation and combating climate change, reducing the impact of anthropogenic activities.

The remainder of the paper is organized as follows: in Section 2, we report the methodology employed, whereas Section 3 describes the data. Section 4 reports the results, and Section 5 offers some concluding remarks.

2. Theory and methods

[1] To assess the impact of "fast-start finance," the dataset refers to the AidData Research Release 2.1 (of which the last year is 2010) because the disbursements are not made available in the new release of the AidData (Released: 2016/04/29), which includes commitments that are not sufficient for evaluating the impact of this policy measure.

The aim of climate finance is the promotion of green growth and, consequently, a reduction in GHG emissions. Bearing this assumption in mind, we believe that countries that have received climate funds have reduced the impact of anthropogenic activities on environment with respect to countries that have not received the funds. On the basis of this assumption, there are differences between treated and untreated countries regarding the convenience of producing electricity by renewable or fossil sources. Because the aim of this paper is to investigate whether these differences are a direct effect of climate funds, quantifying its magnitude, a counterfactual analysis is conducted to compare the *ex post* realized outcome of the treated countries with a counterfactual outcome of the untreated countries that, under certain assumptions, reproduces the *ex ante* situation.

Counterfactuals have been previously used to examine a range of statistical and macroeconometric questions. Abadie and Gardeazabal (2003) examine the effect of terrorism on the Basque. Pesaran and Smith (2016) examine the effects of the quantitative easing introduced in the UK after March 2009. Hsiao, Ching and Wan (2011) study the effect of political and economic integration with mainland China on output growth in Hong Kong, constructing counterfactuals based on predictions from similar economies. In some recent works, PSM is used concerning macro policy evaluation borrowing techniques from the micro literature to obtain an estimate of an average treatment effect. Angrist, Jorda and Kuersteiner (2013), drawing on a previous work (Angrist and Kuersteiner, 2011), estimate the effect of monetary policy. They measure the average effect of policy changes on future values of the outcome variables (inflation, industrial production, and unemployment), inversely weighted by policy propensity scores in a manner similar to that used to adjust non-random samples. Jorda and Taylor (2013) use similar procedures to estimate the effect of fiscal policy. Romano et al. (2016) investigate some specific features related to the energy policy choices of countries, based on the comparison and matching of variables drawn from a macroeconomic panel dataset.

Let us consider that the treatment indicator, I_i, is equal to *1* if individual *i* receives the treatment and otherwise *0*. The match is made based on a score, i.e., the propensity score, which consists of the conditioned probability that each individual will participate in the treatment given by a series of covariates (the control variables chosen to represent the common characteristics of the individuals). One possible identification strategy is to assume that, given a set of observable covariates X, which are not affected by the treatment, the potential outcomes are independent of the treatment assignment. The implication is that selection is solely based on observable characteristics and that all variables that influence the treatment assignment and potential outcomes are observed simultaneously.

The application of the PSM technique requires the execution of several sequential steps (Rubin, 1997):

1. A variable indicator I_i is fixed for each individual, assuming the value of 1 if the individual results as being treated and otherwise 0.

2. The evaluation of a probit/logit regression model of the following type:

$$\pi_i = \alpha + \sum_{j=1}^{k} \beta_j x_{ij} \tag{2.1}$$

3. The creation of a vector of the propensity scores composed of *i*-scalers, each of which is equal to the following:

$$p_i = \Phi(\pi_i) = Prob(I_i = 1|X) \tag{2.2}$$

where φ(·) is the cumulative distribution function (cdf) of a normal distribution (if one has chosen to estimate the scores with a probit model) or a logistic distribution (if one has chosen to estimate the scores with a logit model) and X is the vector of the covariates included in the model as control variables. It ensures that individuals with the same X values have a positive probability of being both participants and non-participants (Heckman et al. 1999).

4. The matching, based on the similarity of the scores, of the individuals treated with those untreated.

The most frequently utilized *matching* method is *nearest neighbor matching* (Rosenbaum and Rubin, 1983). This procedure consists of matching to each treated individual another untreated individual who has the nearest numerical propensity score.

Once the match has been made, the parameter that received the most attention in the evaluation literature is the average treatment effect on the treated (ATT), which is defined as follows:

$$ATT_i = E(t_i|I = 1) = E[(Y_i(1)|I = 1] - E[(Y_i(0)|I = 1] \quad (2.3)$$

where Y(1) represents the value of the variable *Y* of the *i-th* individual exposed to the treatment and Y(0) represents the value that would have been for the same individual in the absence of treatment. Because the counterfactual expected value $E[(Y_i(0)|I = 1]$ is not observed for the treated, it is approximated with the value of the most similar *j-th* individuals in terms of the propensity scores. Equation 2.3 becomes:

$$\begin{aligned} ATT_i &= E[(Y_i(1)|I = 1] - E[(Y_i(0)|I = 1] \\ &= t_{ATT} + E[(Y_i(1)|I = 1] - E[\left(Y_j(0)\right|I = 0] \end{aligned} \quad (2.4)$$

The difference between the left-hand side of equation 2.4 and t_{ATT} is the so-called self-selection bias that is not observed; the lower it is, the better defined is the propensity score model.

The algorithm that serves as the basis of *nearest neighbor matching* predicts that each untreated individual, once he or she is matched, is re-inserted into the procedure to be possibly matched to another treated individual that is, however, numerically near it (based on a predefined margin). For this reason, at the end of the procedure, each untreated individual can be:

a) matched to only one treated individual

b) matched to more than one untreated individual

c) unmatched

To be effective, the matching should balance the characteristics across the treated and respective matched comparison groups. To evaluate whether this objective has been achieved, the results of the matching can be explored by inspecting the distribution of the propensity scores in the treated and matched comparison groups. These should appear similar. Observable differences should raise concerns over the success of the match. The comparison of the summary statistics of the covariates used for the matching between the treated and matched groups is another important indicator of the degree to which the matching has been successful in balancing.

3. Data

To analyze the effectiveness of climate funds and assess the impact on the environmental performance of countries, we investigate how the climate funds destined to "Energy generation and supply" and to "General environmental protection" have helped countries to move toward a reduction in the effect of anthropogenic activities on the atmosphere and how these funds promote economic growth. To reach these goals, we use a large dataset of 149 countries that includes countries that have received funds in 2010 (treated – 83 counties) and those that did not receive funds (untreated – 66 countries). Furthermore, the variables can be grouped as target and control indicators.

Untreated countries, although similar to treated countries in terms of the control variables, have a different behavior in terms of the target variables because the former (control variables) are not affected by climate funds whereas the latter (target variables) are. These differences, under the hypothesis that, without the funds (received two years before), the treated countries would be similar to the untreated countries, also in terms of the target variables, are quantified and interpreted as the effects of the policy (Rajeev and Sadek, 2002).

Among the target variables, we include:

those for which climate funds aim to increase:

i) the share of renewable energy in the total energy generated *(shren*);

ii) electricity generation (*elgen*): the electric power generated from other sources of primary energy weighted for the share of the population covered by electric grids; and

iii) per capita GDP (*gdp*);

those for which climate funds aim to reduce:

iv) per capita CO_2 emissions (*co2*), proxy for total GHG emissions; and

v) the share of fossil energy in the total energy generated *(shfoss*).

In the group of control variables, we consider those typically indicated by the previous literature (see, e.g., Marques et al., 2011; Romano et al., 2015 and 2016) as key factors that drive countries toward increasing generation from renewable energy sources: electricity consumption, the oil supply, energy intensity, the female population and the population growth rate.

The electricity consumption variable (*elcons*) is included in the group of control variables because, in several macroeconomic analyses, it is commonly assumed that it is a proxy for the level of economic development. Richer countries are able to better promote investments in renewable energy sources (RESs) by employing different forms of grants and incentives (Romano and Scandurra, 2014; Romano et al., 2015). However, higher incomes can imply additional electricity consumption, that is, from available fossil generation, to maintain citizens' perception of their quality of life (Marques et al., 2011). The increase in energy consumption can lead policymakers to build new RES power plants, taking advantage to reach this aim through the climate funds. The total oil supply (*oil*), measured in terms of the production of crude oil (including lease condensate), natural gas plant liquids and other liquids, and the gain in refinery processing, is included in the group of control variables because, with this indicator, we can control for lobbying effects (see, e.g., Marques et al., 2011; Marques and Fuinhas, 2012). Where these resources are used intensively, we expect a poor propensity for the usage of climate funds by countries. In this group, we also include energy intensity (ei). As argued by Romano et al. (2015), more developed economies are also oriented toward production efficiency improvement and low-energy intensity, and for these reasons, the ratio between energy consumption and GDP can be considered a proxy for technological and economic progress. Because our dataset contains mainly developing countries, which are more oriented toward the use of traditional energy sources, a poor propensity for the usage of climate funds by countries is expected. The share of the female population (*female*) is included because it has been shown that women have stronger preferences for environmental issues and protection (see Zhao et al., 2012). Thus, this variable can represent a proxy for the population's preference for a greener policy management, i.e., an indicator of a 'green sentiment' and, consequently, an indicator of the positive sensitivity of the population regarding the use of climate funds. Population growth has a far-reaching influence on carbon emissions (Feng et al., 2013). Furthermore, we expect that, to meet the global demand for energy, countries with a high population growth rate (*popgrow*) may be more interested in climate funds.

The definitions, data sources and descriptive statistics of the target and control variables for the sample (149 countries: treated and untreated) are reported in Table 3.1.

Table 3.1. ABOUT HERE

4. Results and discussion

The main purpose of climate funds is to help developing countries promote green growth. Our analysis can help illuminate what has been achieved during the "fast-start finance" period and to draw lessons for international climate finance in the years ahead, when the GCF produces its effects. Coherently with the logical scheme of the econometric strategy, the three steps specified in this paragraph are performed. The first regards the results of the probit propensity score model in terms of the analysis of the determinants driving countries to receive climate funds; the second focuses on the impact that the funds have on the treated countries in terms of effect of the treatment; and, in the third, a supplementary analysis of the tradeoff between fossil and RES generation is conducted.

4.1 Propensity scores matching and balance

The coefficients of the propensity score probit model are reported in Table 4.1. They respect the expected signs and are in line with the results of several recent analyses of the determinants that drive policymakers in energy policy decisions (see, e.g., Marques and Fuinhas, 2012; Romano et al., 2015; Aguirre and Ibikunle, 2014; Romano et al., 2016).

Table 4.1. ABOUT HERE

The results of climate funds are more attractive for countries characterized by increasing population growth rates and high levels of energy consumption. In these countries, most likely, the growing population, intensified agricultural practices, an increase in land use and deforestation, industrialization and the associated energy use of fossil sources have all led to the increased growth rate of GCF abundances in recent years. For this reason, the GCF focuses attention across them by investing in low-emission and climate-resilient development with its financial mechanisms. As expected, the results of climate funds are also very attractive to countries where the population's preference for a greener policy management is higher. By contrast, oil-exporting countries and those that are more oriented toward the use of traditional energy sources (high energy intensity) prove to be more resistant to these types of policies in support of renewable energy generation because they imply structural changes in their generally well-defined industrial structures and economic systems. The fact that the results of the probit model confirm several consolidated issues is an important starting point for the next step of the work, which concentrates on the analysis of the impact of the funds on the countries that have obtained them. Moreover, the matching performed using the fitted values of the model (the propensity scores) ensures that the similarities between matched countries are respected, with the only exception being *energy intensity*; the average values of the control variables of the untreated countries are not significantly different from those of the countries to which they have been matched (Table 4.2 column 2).

Tab. 4.2 ABOUT HERE

Additionally, the distribution of the scores of treated and untreated countries (Fig. 4.1) confirms that the propensity score model is able to capture the similarities between the two groups.

Fig. 4.1. ABOUT HERE

4.2 Estimating the effectiveness of climate funds: the treatment effect

The treatment effect on treated (ATT) represents a comparison between the observed values and the expected values of the target variables for the treated countries if they had not participated in the treatment. Countries that have received funds, in fact, are similar, in terms of the control variables, to the countries that have not received funds to which they have been matched. However, they are different in terms of the target variables, and the basic hypothesis is that this difference is due to the treatment. Table 4.3 reports the values of the estimated ATT; analyzing its results, it emerges that electricity generation in treated countries is, on average, significantly higher than that in untreated countries. Following the logical scheme of the previous issues, this result can be interpreted as a growth in efficiency in electricity-generation processes.

In terms of CO_2 emissions, without the funds, there would have been no differences between treated countries and their similar matched countries. Instead, the significant reduction in the per capita CO_2 emissions of treated countries is a result that is in line with the theoretical background of this paper and with the global climate finance architecture. Climate finance mechanisms, in fact, are conditioned to efforts to reduce emissions. However, although expected, this result is helpful in quantifying the effects of the main aim of this policy.

Focusing on per capita GDP, we observe another difference between treated and untreated countries. On average, the GDP of countries that have received funds increases approximately 1,600 euro with respect to that of the counterfactual part. This result confirms those of several recent studies on the positive effects of climate financing on the economies of developing countries (Jakob et al. 2015, Ellis et al. 2013), with renewable energy being a crucial component for the economic growth of developing countries (Saidi and Ben Mbarek, 2016).

Observing the estimation results, we note that treated countries have, on average, a share of energy produced by renewable sources (RES) that is significantly higher with respect to their similar untreated countries by approximately 20 percentage points. Complementarily, the share of energy produced by fossil fuel is significantly lower, on average, by approximately 21% with respect to the counterfactual part of countries. Without the funds, they would also be similar in terms of the target variables, and these differences, in fact, are due to the climate funds that, having been disbursed at least two years ago, have increased the share of electricity generated by RES. This important result suggests that climate finance can help countries increase investments in RES generation and can substitute for fossil power generation.

Tab. 4.3 ABOUT HERE

4.3 Explaining the substitution effect between fossil and RES generation

To better investigate the last issue that emerged in light of the results of the treatment effect, we propose a supplementary detailed analysis based on the utility of fossil and renewable generation. The substitution effect on the optimal choice of Renewable (θ_1) and Fossil (θ_2) generation is a disputed point in the literature. A recent work by Salim et al. (2014) using a panel dataset of OECD countries shows that there is a long-term equilibrium relationship among non-renewable and renewable energy sources. Other studies (see, e.g., Al-mulali et al., 2014) show that countries that increase their investment in renewable energy projects increase the role of electricity consumption from renewable sources compared to that from non-renewable sources.

The substitution effect revealed in terms of the sources of energy generation induces not only a reduction in CO_2 emissions but also an increase in electricity generation and, consequently, an increase in their utility[2].

For the sake of simplicity, we consider that the utility of electricity generation can be a function of RES (θ_1) and fossil generation (θ_2), U(θ_1, θ_2).

This utility function represents the level of satisfaction obtained by a country as a function of its capacity to generate power; thus, the level of utility *U* is measured in terms of electricity generation. The reason for this choice is based on the assumption that, in the decision on the amount of electricity generation, policymakers examine the tradeoff between the necessity to support economic operators and the concerns for preserving natural resources and the environment. The hypotheses underlying this assumption are that, in managing the tradeoff, policymakers are faced with a direct choice regarding how to compose the basket of sources of energy to generate electricity. The former are consolidated, less expensive and more established to support the productive processes but have a stronger environmental impact, whereas the latter require investments and structural resizing but have a higher degree of sustainability (Weigelt and Shittu, 2016; Nazari et al. 2015).

The optimal pair of function settings (θ_1, θ_2) is that for which the transformed utility *U* is maximized under the budget constraint:

$$Y = C_1\theta_1 + C_2\theta_2 + (\bar{F}\theta_1 \mid \varepsilon X) \quad 4.1$$

where C_1 and C_2 are the unit costs of energy generated by renewable and fossil sources, respectively, and $\bar{F}$ is the average amount of each climate fund's policy supported by GCF. Consequently,

[2] Previous studies of the application of utility functions to energy generation have explored how they can be used to quantify and manage the tradeoffs in the production processes between emissions and energy consumption (Sims et al., 2003; Noblet et al., 2015; Pohekar and Ramachandran 2003). They are more concerned with issues such as costs and investments. In this work, we want to analyze the tradeoff between fossil and RES generation.

developing countries that are involved in reducing, with a target ε ($0<\varepsilon\leq1$), their GHG emissions (*X)* to enforce renewable energy generation projects can benefit from various instruments by using different and multiple policies (Romano et al., 2017). For untreated countries, i.e., countries that are not disbursed funds, F = 0; for treated countries, the higher the ε is, the greater the amount of $\bar{F}$. Maximization can be obtained through the Lagrange multiplayer method:

$$L = U(\theta_1, \theta_2) + \lambda(Y - C_1\theta_1 - C_2\theta_2 - [\bar{F}\theta_1 \mid \varepsilon X]) \quad 4.2$$

and its partial derivatives:

$$\frac{\delta L}{\delta \theta_1} = u(\theta_2) - \lambda(C_1 - [\bar{F}|\varepsilon X]) = 0$$

that is,

$$u(\theta_2) = \lambda(C_1 - [\bar{F}|\varepsilon X]) \quad 4.3$$

and

$$\frac{\delta L}{\delta \theta_2} = u(\theta_1) - \lambda C_2 = 0$$

that is,

$$u(\theta_1) = \lambda C_2 \quad 4.4$$

Equation 4.3 indicates that, for untreated countries, which have $\bar{F}$=0, only the unit costs of renewable energy, C_1, influence the choice regarding the amount of fossil energy sources, θ_2, for determining the optimal level of electricity generation. For treated countries, the amount of $\bar{F}$, related to the GHG emissions reduction targets, is also considered. In particular, for these countries, the greater the emissions reduction target is, the higher the amount of funds, $\bar{F}$, and the lower the burden of fossil energy sources, θ_2, in determining the optimal level of electricity generation.

Under the assumption of a multiplicative form of energy utility functions (see, e.g., Pohekar and Ramachandran 2004; Silva et al., 2015):

$$U = \prod_{j=1}^{n} k\theta_j^{u_j}$$

where k is an overall scaling constant and $u_j(.)$ is the utility function operator for each attribute j. The country's utility value can be represented by a linear logarithmic function:

$$\log(U)=\log(k) + u_1\log(\theta_1) + u_2\log(\theta_2) \quad 4.5$$

The parameters of equation 4.5, i.e., k, u_1 and u_2, represent the elasticities of θ_1 and θ_2 and have been estimated by OLS both for the function of untreated countries (66 observations) and for the function of treated countries (83 observations). They are all significant (at the level of 99.9%) and very different. In fact, for the countries that have received climate funds, the elasticity of θ_1 is higher with respect to the elasticity of θ_2. The result for the countries that have not received climate funds is the opposite. Figure 4.2 reports the representation of the elasticities for treated and untreated countries.

Fig. 4.2 ABOUT HERE

The figures lead us to confirm that both estimated utility functions respect the theoretical assumption of Equation 4.3. Countries that receive climate funds are incentivized to promote the use of energy by renewable sources for the higher benefits obtained in terms of electricity generation. In fact, in these countries, a unit increase in the use of energy by renewable sources implies a growth in electricity generation that is higher than what would have occurred if the same increase concerned the use of energy by fossil sources. The increasing deployment of RESs has positive impacts in a number of key areas such as climate change mitigation, by reducing the impact of anthropogenic activities on the atmosphere, and energy security, by reducing the demand for imported fossil fuels and energy efficiency.

6. Conclusions

Climate funds are partnering with a growing variety of international and developing country-based institutions; the number of implementing agencies has expanded from the three original organizations to approximately 40 institutions (Nakhooda and Norman, 2014): regional development banks, international organizations, developing country ministries, trust funds and NGOs. Moreover, because their official scope is to help the institution to combat climate change, in this paper, we have derived a model to evaluate the effectiveness of a policy intervention based on the differences, over a given policy evaluation horizon, between the post-intervention realizations of the target variables and the associated counterfactual outcomes.

The combined interpretation of the results seems to provide positive responses to the research questions of the paper regarding the effectiveness of climate finance initiatives. Climate funds have a positive effect in terms of reducing the electricity generated by fossil sources and, consequently, in terms of reducing CO_2 emissions. Another important result that arises from the analysis is that, in the recipient countries, a substitution effect between fossil and renewable sources in electricity production occurs: the increase in energy produced by renewable sources balances the fossil part that is no longer produced.

The results confirm that climate funds reduce the magnitude of the fossil contribution to the overall energy utility of the countries in which the funds are distributed.

Incentivizing this replacement does not imply negative consequences for economic growth because, from the analysis, positive effects in terms of energy efficiency and in terms of an economic stimulus to reach sustainable development also emerge. The results of the analysis, in fact, show that, in the recipient countries, with respect to the counterfactual part, an increase in both electricity generation and per capita GDP occurs.

This paper analyzes the overall effectiveness of all of the funds in all of the recipient countries, but in some cases, climate finance may have failed. After all, it has now been more than two decades since the problem of climate change became a topical issue, and only little progress in implementing the global agreement to limit the increase in temperature to 2°C has been made. In the light of these considerations, we think that further studies are needed to help researchers investigate whether climate finance is a path on which to continue or whether we must arm ourselves with other instruments to support this objective. Furthermore, because, in the literature, increasing interest in the existence of a substitution effect between RES and fossil sources in electricity production systems has begun to form and, to evaluate the instruments to limit climate change, studies are still going through a learning phase, this work can represent a starting point to begin a discussion on this relevant research topic and to make a contribution to the actual literature.

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Tables and Figures

Table 3.1. Data: Definitions, descriptive statistics and sources.

Label	**Variable**	**Unit**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Source**

Control Variables							
elcons	The electric consumption (log of) is the electric power consumption equal to the sum of total net electricity generation and electricity imports net of the electricity exports and electricity transmission and distribution. losses	Billion Kilowatt -hours	1.55	2.36	-3.84	8.24	The U.S. Energy Information Administration (EIA)
oil	Total Oil Supply includes the production of crude oil (including lease condensate), natural gas plant liquids, and other liquids, and refinery processing gain.	Thousan d Barrels Per Day	464	1,429	-0.54	10,908	
ei	Energy intensity using purchasing power parities is calculated by dividing the data on total primary energy consumption in quadrillion British thermal units for each country and year by the gross domestic product using purchasing power parities in billions of (2005) U.S. dollars for each available country and year.	Btu per Year 2005 U.S. Dollars (PPP)	6,759	6,215	199	50,976	
female	Female population is the percentage of the population that is female	% of total	49.74	3.48	24.65	54.31	World Bank (World Development Indicators)
popgrow	Population growth rate	annual %	1.70	1.56	-2.10	10.40	
Target Variables							
shfoss	Fossil Fuels electricity generation consists of electricity generated from coal, petroleum, and natural gas.	% of total	0.66	0.34	0.00	1.00	The U.S. Energy Information Administration (EIA)
shren	Renewable electricity generation includes generation from hydroelectric and not hydroelectric sources	% of total	0.33	0.34	0.00	1.00	
elgen	Indicator of electric power generated from all sources. Ratio between electric power generated and share of population covered by electric grids	Billion Kilowatt -hours	69.51	350.96	0.02	4,051	
co2	Per capita carbon dioxide emissions including Land-Use Change and Forestry	Million metric tons	4.09	6.49	0.03	46.7	World Bank (World Development Indicators)
gdp	GDP per capita based on purchasing power parity (PPP). PPP GDP is gross domestic product converted to international dollars.	Constant 2011	12,367	16,274	698	127,670	

Tab. 4.1 Coefficients and goodness of fit statistics of the probit propensity score model (std. errors are in parenthesis)

Variable	Coefficient
intercept	*-4.7212*
	(0.0697)

log(elcons)	0.3688***
	(0.0697)
oil	-0.0003**
	(0.0001)
log(ei)	-0.3694**
	(0.1665)
female	0.1442**
	(0.0655)
popgrow	0.2245*
	(0.1206)
Loglikelhood	-81.4814
Pseudo R^2	0.3265
Significance: 0.001 '***' 0.01 '**' 0.05 '*' 0.1	

Tab. 4.2 Tests of balance: similarities of means of the control variables before and after matching

	Before Matching	After Matching
	log(elcons)	
Mean Treated	2.2136	2.2136
Mean Untrated	0.7167	2.5152
p-value	0.0001	0.1424
	oil	
Mean Treated	407.1200	407.1200
Mean Untrated	535.0500	268.9200
p-value	0.6155	0.2911
	log(ei)	
Mean Treated	8.4311	8.4311
Mean Untrated	8.5444	8.7647
p-value	0.4435	0.0046
	female	
Mean Treated	50.2560	50.2560
Mean Untrated	49.0910	49.9850
p-value	0.0697	0.5506
	popgrow	
Mean Treated	1.6457	1.6457
Mean Untrated	1.7591	1.7123
p-value	0.6837	0.8174

Tab. 4.3 Average treatment effects on treated

Variable	ATT
shren	0.2052
	(0.0149)

shfoss	-0.2100
	(0.0154)
co2	-7.0423
	(0.0008)
elgen	0.8649
	(0.0850)
gdp	1,606.7
	(0.0150)

Fig. 4.1 Scatterplot of propensity scores of treated and untreated countries

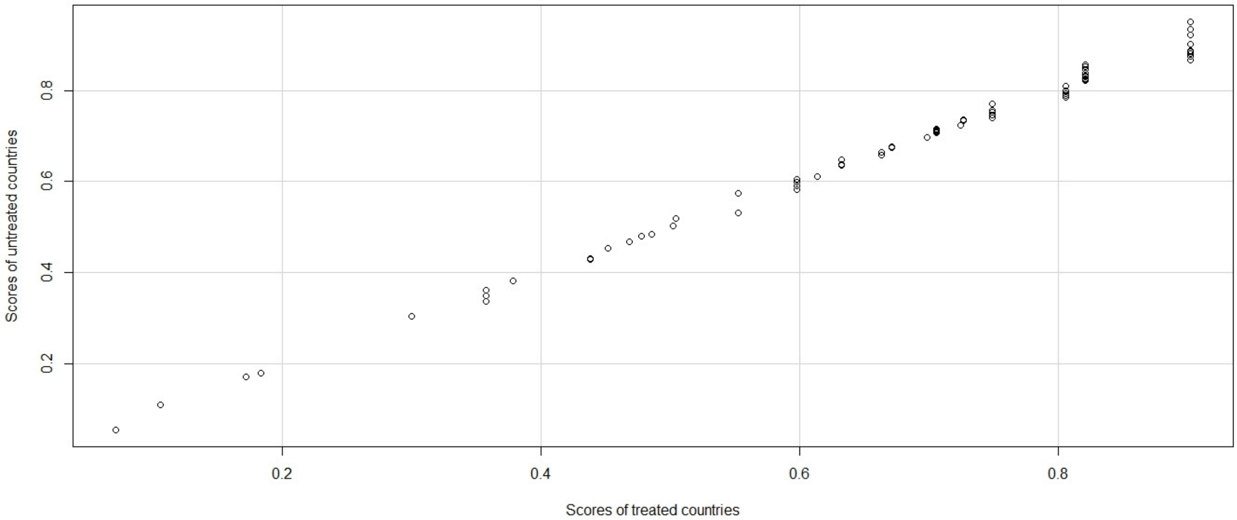

Fig.4.2 Marginal effects for treated and untreated countries