Does climate aid matter for reducing CO2 emissions? The case of foreign aid for renewable energy.

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Abstract:

This article aims to investigate how climate aid devoted to renewable energy contributes to CO2 emissions in recipient countries. Indeed, since the beginning of the 2000s, international agreements between developed and developing countries have promoted the provision of financial aid to the second group of countries to help them fight global warming. We first discuss stylized facts on climate finance devoted to renewable energy and its impact on CO2 emissions. We can see that while the first variable is quickly increasing, the second variable displays a decrease from 2010. Econometric results show that climate aid for renewable energy has a slight impact on CO2 emissions reduction, especially after a threshold. However, despite this optimistic result, the impact is transitory. Indeed, this result can be explained by the fact that developing countries are more preoccupied by economic efficiency than ecological efficiency. However, in countries where a carbon tax is set, the tax contributes to reducing CO2 emissions. Finally, we show that ecological technologies imported through foreign direct investment do not yet play a significant role in reducing CO2 emissions or CO2 intensity.

Classification JEL: F64; O18; Q28; Q56

Keywords: Climate change, Climate aid, CO_2 emissions, Renewable energy, Generalized Moment Method.

1. Introduction

Climate change due to global warming is among the most profound long-term challenges all countries, advanced as well as developing economies, will face over the coming years (IPCC 2014, 2018). Despite climate change mitigation and adaptation agreements, CO_2 emissions from fossil fuel combustion (the main greenhouse gases (GHGs) that react as a 'blanket' on the Earth's surface and are responsible for global warming) are still increasing at the global level, Le Quéré et al. (2019).

According to the recent EDGAR report of the European Commission (2019), these anthropogenic emissions increased in 2018 by 1.9% compared to the previous year, reaching a total of 37.9 $GtCO_2$.
In addition to these challenges of a rapidly warming planet, the world faces biodiversity loss, water scarcity, ocean acidification, pollution (air and water), deforestation, and other types of environmental degradation. The resulting issues have a heterogeneous impact across countries (Standard & Poor's, 2014). Low-income countries in Africa, Asia and South America are the lowest emitters, but they suffer greatly because of their geographical location.

The international awareness of climate change risks has been growing, leading to enhanced international actions to reduce emissions and limit global warming to temperatures below 2°C, as agreed in the 2015 Paris Agreement. Under this agreement, developed countries have committed to continuing their existing collective goal to mobilise USD 100 billion per year by 2020 and extend this goal until 2025 for financing climate initiatives, covering mitigation and adaptation actions (efforts to limit climate change and adapt to it) in favour of developing countries.

The Paris Climate Agreement urges developed countries to significantly increase adaptation finance from current levels and to provide more support for capacity building and appropriate technology. It also encourages developing countries, including emerging economies, to provide or continue to provide climate finance voluntarily. Indeed, economic development is achieved through production processes that can be more or less polluting.

In the past, no economies were aware of the pollution supported by the whole earth and the environment. However, while the environment is a global good, global warming is free and has negative consequences even on those who do not take part in it. As a result, the pollution from industries in industrialised regions can indirectly harm small islands threatened by floods. Because of this inherent feature of public goods, developed economies bear the responsibility of the major CO_2

emissions through their industrialisation. For instance, China, the United States, India, the 28 nations of the European Union, Russia and Japan are the world's largest CO_2 emitters. Together, they account for 51% of the population, 65% of global GDP, and 80% of total global fossil fuel consumption and emit 67.5% of total global fossil fuel CO_2. For comparison, Africa represents 4% of the total global fossil fuel CO_2 emissions.

In this context, global warming has been addressed commonly by developed and developing economies. In fact, developing countries cannot implement adaptation and mitigation against global warming alone. Again, there is a kind of contradiction between economic growth and the protection of the environment. Indeed, as stated above, economic production is usually accompanied by pollution. Therefore, the financing of this economic development should encompass the fighting of global warming through the financing of development projects that take into account environmental constraints. This is why developed nations commit to giving financial support to developing countries. Moreover, as outlined by Esposito et al. (2019), "A mandatory part of this effort is sustainable finance: non-green finance is simply unworkable in the long run." For example, it is estimated that by 2030, the world will need to invest close to USD90 trillion in sustainable infrastructure assets in key areas, such as buildings, energy, transport, water and waste, to tackle three central challenges facing the global community.

Developing countries, whose main aim is economic development, have to account for global warming in their development strategy. This is why developed economies have begun transferring aid to developing economies. Indeed, global warming is a common issue that has to be addressed by both developed and developing countries. The former must help the latter address this issue while pursuing development and growth. Indeed, as we mentioned above, pollution in countries in the global North first affects countries in the South, where the climate is warmer and where the effects of global warming appear first. For example, the Amazon rainforest contributes to the regulation of the whole earth's climate. Therefore, it is necessary to address this issue globally and help developing countries adopt less polluting processes of production and development.

Given these issues, this paper sheds light on whether climate aid from developed countries to developing countries by international agreement has started to contribute to emissions reductions in the underlying recipient countries. Our objective in this study is twofold: first, we analyse the trend (stylised facts) of global climate finance and carbon emissions, especially CO_2 emissions, in developing countries. Second, we investigate how other factors regarding climate policies can contribute to managing emission reduction. No previous paper in the literature uses foreign aid for renewable energy and therefore closely addresses the impact of climate aid on CO_2 emissions. As we will discuss in the literature review, articles on the topic of foreign aid use the total amount of foreign aid and consider the impacts on CO_2 emissions or energy intensity. This procedure does not offer a new discussion of how the international community can help developing countries make use of cleaner processes of energy production to fight global warming. In contrast, in the present study, we use the Creditor Reporting System (CRS), which provides sectoral foreign aid data. Therefore, we are able to obtain a more refined level of foreign aid and assess its impact on development projects devoted to fighting global warming. To the best of our knowledge, this is the first study that uses sectoral foreign aid to address the impact of the share of foreign aid devoted to environmentally friendly projects in order to assess the impact on CO_2 emissions.

Our results are as follows: Climate aid proxied by foreign aid for renewable energy negatively affects CO_2 emissions. The reduction is significant but not persistent. In addition, there is a threshold amount of climate aid beyond which this impact is effective. We find the same result concerning the impact of climate finance on CO_2 intensity, which grasps the environmental impact of economic activity. This impact is also transitory. In addition, there is a positive and significant relationship between CO_2 intensity and variables such as GDP, investment and industry, which corroborates our previous findings. Again, this result indicates that developing countries are more preoccupied by economic efficiency than ecological efficiency. New industrialized countries as well as oil exporting countries do not display different patterns than other developing countries. However, in countries where a carbon tax proxied by the diesel price is applied, we can observe a negative and significant impact on CO_2 emissions. This implies that policies that discourage the use of more polluting sources of energy are efficient in fighting global warming. Finally, innovative ecological technologies, which are imported into developing countries through foreign direct investment, do not yet play a significant role in reducing CO_2 emissions or CO_2 intensity.

The paper is structured as follows. Section 2 presents a review of the relevant literature concerning carbon dioxide emissions and climate-aid. We also analyse stylised facts with data on CO_2 emissions and climate aid. Section 3 addresses the data sources, methodology and interpretation of the results. The conclusion of the paper is presented in Section 4.

2. Literature review and stylised facts

2.1 Literature review on the link between foreign aid and CO_2 emissions

In this article, we are interested in the impact of foreign aid for renewable energy on CO_2 emissions. Indeed, foreign aid for helping developing countries cope with the requirements of international agreements is regularly discussed during the Conferences of Parties (COPs). According to OECD (2019), the total climate finance provided and mobilised by developed countries reached USD 71.2 billion in 2017, up from USD 58.6 billion in 2016 (a 21% increase). This includes four components: bilateral public finance, multilateral public finance, officially supported export credits and mobilised private finance. Since this paper is interested in green finance from donors to developing countries under the OECD-DAC programme, at a sector level, it will focus on sectors where the positive impact in terms of emission reductions may be more tangible, such as green projects for energy generation and renewable resources in developing countries. The objective is to analyse whether these projects are in line with climate-resilient pathways.

Several articles have examined the impact of foreign aid on reducing CO_2 emissions in developing countries. For instance, Arvin et al. (2006), using Granger causality tests and cointegration analysis, find that foreign aid is detrimental to pollution for the whole sample of developing countries. Especially, for countries with upper income which are mostly new industrialised countries. However, when considering low-income countries, the pattern is different, in the sense that more aid leads to less pollution. Arvin et al. (2006) also find that donors do not increase the level of aid to countries that reduce their level of pollution. Again, Arvin and Lew (2009) test the impact of aid per capita on CO_2 emissions, water pollution and deforestation. They find that an increase in per capita aid reduces CO_2 emissions, water pollution and deforestation. However, countries receive more aid to reward them for forest protection than for other types of ecological injury.

These two previous studies do not take into account country heterogeneity. Kretschmer et al. (2011) address this heterogeneity by incorporating in their regression several explanatory variables that can grasp this heterogeneity. In addition, they consider the composition of foreign aid by distinguishing foreign aid for industry and foreign aid for energy. They also find that aid has no significant impact on CO_2 emissions. Again, Boly (2018) assesses the link between foreign aid and CO_2 emissions in aid-recipient countries. His sample is made up of 112 countries over the period 1980 to 2013. He finds no statistical significance of total aid, as shown in previous studies, such as Lim et al. (2015). However, when considering disaggregated foreign aid, that is, bilateral and multilateral aid, he finds that the latter has a significant impact on CO2 emissions. In particular, he finds that bilateral aid is effective when targeted towards the environment and after a certain threshold, implying an inverted U-shaped relationship. Indeed, in addition to the type of donor, the purpose of the aid given to a country can be considered. In particular, when splitting the component of bilateral aid into an environmentally friendly component and an environmentally harmful component, the author finds a negative impact of environmentally friendly aid on CO2 emissions. This result suggests that donors should finance less-polluting activities and more environmentally friendly activities.

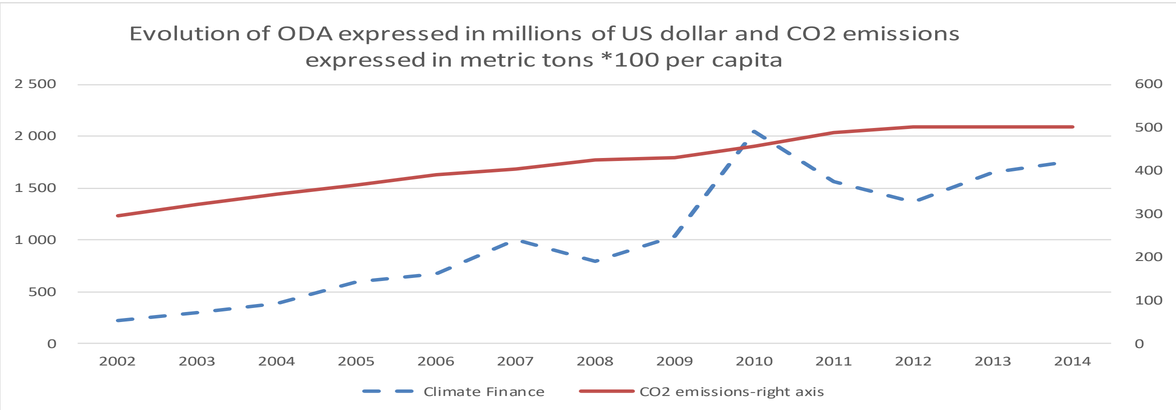
Last, Bhattacharyya et al. (2016) investigate the impact of energy-related aid on CO2 and SO2 emissions for 131 countries over the period 1961 to 2011. They do not find a systematic impact of foreign aid on emissions. They try several robustness checks. Indeed, they check for institutional quality and geographical location. For the first robustness check, they find no significant coefficient related to CO2 or SO2 emissions. However, for the second check, they find a strong difference between geographical locations. Countries located in Europe and Central Asia performed better than other countries in using foreign aid to reduce CO2 emissions. Bhattacharyya et al. (2016) highlight the fact that per capita aid disbursement for power generation over the 2000s has grown by 4 percent, on average, every year. According to the authors, the annualised growth rate of aid commitment in power generation for the same period is approximately 5 percent.

The articles mentioned above only consider data related to foreign aid for energy, regardless of the quality of the source, i.e., polluting or less polluting. They do not use data related to foreign aid for green power generation, that is, foreign aid for renewable energy. In line with the international discussions and agreements taken by nations to reduce CO2 emissions, we believe that this is an important issue to focus on. Indeed, such aid offers a way to replace more polluting power generation processes with new, less polluting processes, which can support more specific efforts to reduce CO2 across countries. We address this issue in our empirical analysis.

2.2 What do statistics tell us about CO2 emissions and climate aid for renewable energy?

Chart 1 depicts the evolution of ODA (Official Development Assistance, gross disbursements) expressed in millions of US dollars and CO_2 emissions expressed in metric tons per capita. We multiplied the CO2 emissions by 100 to represent the two variables that appear in the World Development Indicators (WDIs) with different scales. Therefore, the value represents the average CO2 emissions for low-, middle- and upper-middle-income countries (according to the WDIs) multiplied by 100. We notice that CO2 emissions per capita increase slowly from 2002 to 2014, while climate-related finance increases at a very high pace. At first, one may think that the increase in the financial contribution of developed countries to support the installation of renewable energy does not play a role in the process of the reduction of CO2 emissions. However, this hasty interpretation is false. Indeed, one can notice that, from 2010, CO2 emissions per capita are stagnating, which could induce climate aid to play a role in slowing the increase in CO2 emissions for developing countries.

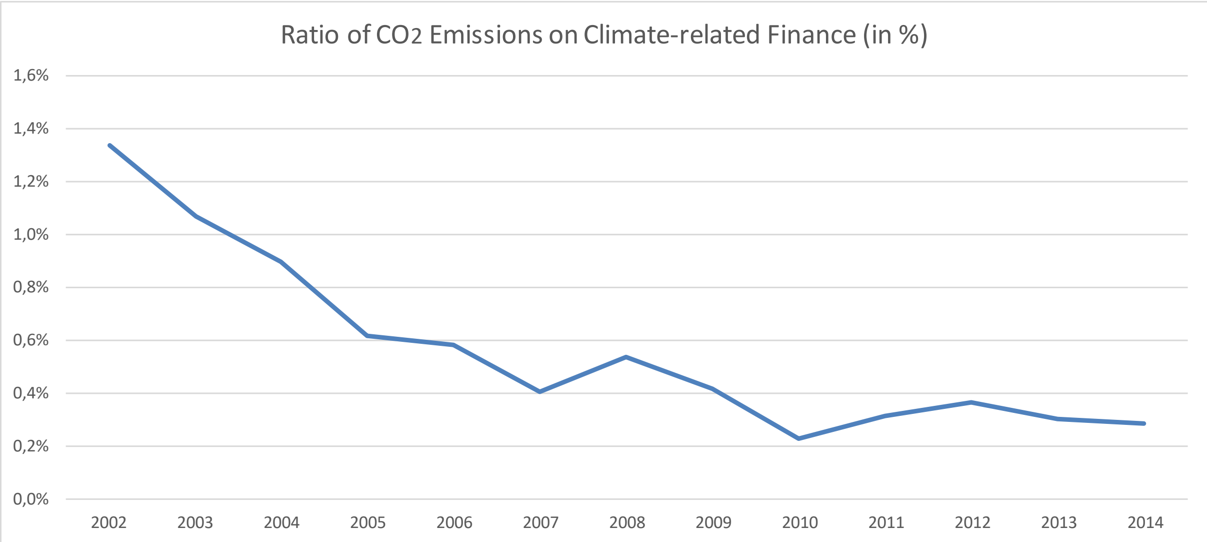
Figure 1: Evolution of ODA expressed in millions of US dollar and CO2 emissions expressed in hundred metrics tons per capita



Climate-related finance for renewable energy (millions of US dollars), source CRS, OECD. CO2 emissions (metric tons per capita), source, WDI, World Bank.

Furthermore, we calculate the ratio of CO2 emissions to climate aid. Figure 2 shows that this ratio is dramatically decreasing throughout the period. In particular, it decreases sharply from 1.4% to 0.4% from 2002 to 2007, and then the decrease is slower, from 0.4% to 0.3%, from 2008 to 2014. The trends before and after 2007 are different, indicating the impact of the subprime crisis. Indeed, because the subprime crisis severely impacted developed countries, they reduced their financial contributions to developing countries, Kablan (2013). The impact of the subprime crisis is also noticeable, as the ratio of CO_2 emissions to financial support increased again in 2008, implying the reduction in this support and the hampering of its effect on curbing CO_2 emissions. This is consistent with the dip in financial support in 2008 due to the subprime crisis, shown in Figure 1. To summarise, the two figures indicate that financial contributions to renewable energy help curb CO_2 emissions in developing countries. This is in line with the hypothesis that we set in response to our research question. In the remainder of our paper, we analyse the impact of this climate-related finance for renewable energy on the CO_2 emissions of developing countries.

Figure 2: Evolution of the ratio of CO2 emissions to climate aid



Climate-related finance for renewable energy (millions of US dollars), source CRS, OECD.
CO2 emissions (metric tons per capita), source, WDI, World Bank.

3. Empirical analysis

In this section, we try to estimate the impact of foreign aid (ODA) on the reduction of CO_2 emissions through investment in renewable energy sources. In the literature, some authors have focused on the impact of foreign aid on the environment in developing countries. Arvin, Dabir-Alai and Lew (2006) have shown that development aid can have a negative impact on pollution for upper-middle income countries because these countries are in a transitional phase of development, while for low-income countries, development aid can reduce pollution. Jorgenson (2007) shows that foreign investment in the industrial sector of developing countries increases carbon emissions and organic water pollutants. Kretschmer, Huber and Nunekam (2011) attempted to answer this question by introducing into the regression the following control variables: the investment ratio, industry's share of GDP, the import ratio, and foreign direct investment. These authors innovate using sectoral aid as a development aid variable, while in previous studies, total aid was used to assess the effect of foreign aid on CO_2

emissions in developing countries. That is, their study distinguishes between aid to industry and aid to energy. They find that foreign aid reduces countries' energy intensity but has no specific impact on carbon emissions. In the same vein, Kablan (2013) tests the impact of foreign aid for renewable energies on CO_2 emissions. She shows that development aid contributes to the reduction of CO_2 emissions, but only after a certain threshold.

3.1 The model

For the empirical analysis, we follow the model proposed by Kretschmer et al. (2011) and Kablan (2013). We use CO2 emissions as the dependent variable in developing countries to take into account the impact of foreign aid for renewable energy on the effort to fight global warming. We consider as explanatory variables CO2 emissions, foreign aid for renewable energy, and other control variables with a lag of one year. Foreign aid for renewable energy is consecutively entered into the model with lags of one to five years. The idea is to assess the impact of foreign aid that will be invested in the production of renewable sources of energy on the reduction of CO_2 emissions. The use of panel data fixed effects or random effects would lead to a bias in the estimates. Indeed, the introduction of the lagged dependent variable introduces endogeneity in our model. In addition, such an empirical specification is unable to deal with unobserved heterogeneity (Nickell, 1981).

In contrast, Arellano and Bond (1991) propose solving this problem by introducing sufficiently lagged values of the explanatory variables as well as instrumental variables, provided that the variables are serially uncorrelated with the error term in the model. More specifically, this method consists of taking the first difference of the estimated equation for each period to eliminate the country-specific effects. Then, the explanatory variables of the first difference equation are instrumented by their lagged values. Furthermore, Blundell and Bond (1998) and Bond et al. (2001) show that the standard first-difference GMM estimator poorly behaves with small samples and gives biased results. Therefore, system GMM proposed by Arellano and Bover (1995) and Blundell and Bond (1998) allows us to circumvent this bias. Indeed, the system GMM combines the equation in first difference with level equations, in which variables are instrumented by their first differences. Moreover, some of the cross-sectional information in levels is retained and exploited in the data more efficiently, and the corresponding estimator has better finite sample properties (Blundell et al., 2000).

Our model has the following specification:

$$\ln(CO2)_{it} = \alpha \ln(CO2)_{it-1} + \beta \ln(aid_{renewgdp})_{it-1,\dots 5} + \gamma X_{it-1} + u_i + v_t + e_{it}$$

where $CO2_{it}$ denotes the CO2 emissions (metric tons per capita) of country i in year t.

aid_renewgdp is the net ODA for renewable energy sources divided by the GDP of country i at year t-1, …, t-5.

X_{it} is a vector of control variables in logarithm;

u_i are country-specific fixed effects, v_t are the year-specific fixed effects and e_{it} is the error term.

We choose CO2 emissions as measured by metric tons per capita to assess the effect on the financing of renewable energy to help mitigate global warming in developing countries. Because CO2 emissions are defined relative to fuel consumption, we introduce the diesel price to control for the use of other energy sources when diesel prices increase. Unfortunately, this variable is only available for a few (70) countries. However, we use it as a control variable for this sample in a robustness check.

As presented in the model, we relate CO2 emissions to the first lag and other explanatory variables, among which *aid_renewgdp* is defined as net ODA for renewable energy sources divided by GDP. As renewable energy sources are alternative sources of energy that are non-polluting, we think that foreign aid intended to foster these sources of energy may have an impact on CO2 reduction. The more a country replaces the consumption of fuel or other non-renewable and polluting sources of energy with renewable energy, the more CO2 emissions will decrease. We introduce five lags of this variable, as foreign aid needs to be used to install renewable energy devices, and it may take time before the devices are usable and have an impact on the reduction of CO2 emissions. We also consider energy produced by renewable sources of energy (renewable), as this represents the willingness of the recipient country to support the replacement of traditional polluting sources of energy by renewable and non-polluting sources. Indeed, Kablan (2013) explains that countries such as Bangladesh and Indonesia show a political will to address climate change. When a country feels concern about global warming and truly takes measures for mitigation, its efforts can have a measurable impact on the reduction of CO2 emissions.

We assume a negative relationship between the two variables. That is, the more electricity from renewable sources a country uses, the less CO2 it will emit. In addition to considering how effectively a country takes measures to address global warming, we introduce a variable that proxies for the quality of governance in the country (qog_icrg) into our model. Indeed, the literature on foreign aid highlights the importance of good governance, foreign aid management and lack of corruption so that financial aid received from abroad can be used in the best way and have the greatest potential of successfully achieving development projects. Burnside and Dollar (2000) and Boone (1996) introduce variables to grasp the political-economic environment and an index of political participation and civil liberties as control variables to assess the effect of aid on growth. In particular, Burnside and Dollar (2000) use aid to interact with their policy variable in a standard growth regression. The variable qog_icrg is an index that captures the quality of governance in a country through the level of corruption, bureaucracy quality, and law and order. This allows us to grasp how well foreign aid is managed and used to fight global warming. Again, Hansen and Tarp (2001) introduce a quadratic term of aid according to the idea that there may be a threshold beyond which finance has no additional positive effect on growth. In our regressions, we consider such a quadratic relationship between aid_renewgdp and CO2 emissions.

Like Kretschmer and al. (2011), we consider GDP per capita to control for the level of development. This could also represent the level of productivity, where a higher value represents a higher level of productivity, which can be associated with lower energy intensity (CO2 emissions per unit of energy produced). In addition, the developed countries have generally strong incentives to reduce their CO2 emissions by using green innovative production processes and less emission-intensive energy sources. For new industrialised countries, because they are in a transitionary phase of development, the relationship between their GDP and CO2 emissions can be negative. Therefore, the sign of GDP per capita is not predefined. It could be positive or negative.

We also consider the investment ratio, measured by gross fixed capital formation as a percentage of GDP and the share of industrial value added in GDP, as in Kretschmer and al. (2011). Indeed, this can have a positive or a negative impact on CO2 emissions. When investment is made in more energy-efficient processes and production equipment, that is, in less emission-intensive facilities, this will lead to a reduction in CO2 emissions. Moreover, if investment is used to install modern renewable energy sources, such as hydro, wind and solar power, it will reduce CO2 emissions. However, investment in inefficient and polluting production materials and sources of energy will increase CO2 emissions. For the share of industrial value added in GDP, we add it into our model to account for the fact that industry is far more energy intensive than agriculture and services. Therefore, we expect a positive sign of the coefficient, as a rising industry share increases the use of energy in the economy.

Last, we consider dummy variables in our model. Here, we talk about the difference between new industrialised countries and developed countries. As our sample is made up of emerging and developing countries, we think that newly industrialised countries may display some specificities. To this end, we consider a dummy variable that is equal to one for a new industrialized county, and zero otherwise. Then, we also consider a dummy for oil producing countries because countries that are oil producers and exporters may have incentives to consume more oil and neglect substituting oil with renewable energy sources. They may be less interested in substitution because oil is cheap and subsidized in those countries. Finally, we consider a dummy for the subprime crisis because many studies on financial support to developing countries show that under the severe effects of the subprime crisis in developed countries, such countries decrease their provision of foreign aid to developing countries, Kablan (2013).

3.2. The Sectoral Foreign aid dataset

The OECD Development Assistance Committee (DAC) Creditor Reporting System (CRS) provides files that contain detailed climate-related finance information from both the recipient and the provider perspectives. Commitments and disbursements are available for the recipient perspective, while only disbursements are shown for the provider perspective.

3.3. Results

First, we perform an OLS regression with fixed effects to serve as a reference. A Haussman test suggests the use of fixed effects instead of random effects. We then consider CO_2 emissions expressed in metric tons per capita as the dependent variable.

The OLS results show that the coefficient of the lag of the dependent variable is significant and positive, along with the GDP per capita and the share of investment in GDP. These positive signs are consistent with the theory, as stated above. Past emissions influenced current emissions, and there is a kind of persistence. The positive effect of GDP per capita is consistent with the idea that a higher level of development for this sample of developing and emerging countries leads to more CO_2 emissions per capita. This result implies that the countries in the sample have not yet achieved the transitional path, when innovations are used to support the reduction in CO_2 emissions. Again, the positive coefficient of investment shows that investment is made to enhance production and development and therefore fosters CO_2 emissions, as not all investments are directed to non-polluting projects.

Finally, the second lag of aid_renewgdp is negative, indicating that climate aid for fostering the use of renewable energy helps reduce CO_2 after the second year. However, this effect is not persistent.

Table 1: Estimates of the relationship of climate finance and CO2 emissions

Econometric Method	OLS	Generalized Moment Method			
	CO2 emissions metric tons per capita				
L.lco2_emi	0.436	0.799	0.666	0.485	0.690
	(7.83)**	(5.27)**	(5.21)**	(2.78)**	(4.72)**
L.aid_renewgdp1	0.003	18.535	16,281.105	18,876.818	14,235.285
	(0.60)	(0.49)	(1.49)	(1.27)	(1.34)
L2.aid_renewgdp1	-0.010	-60.092	-14,960.319	-30,057.461	-19,944.150
	(2.01)*	(2.12)*	(1.15)	(2.56)*	(2.09)*
L3.aid_renewgdp1	0.004	41.946	14,082.142	6,516.760	9,510.949
	(0.78)	(1.30)	(1.52)	(0.60)	(0.96)
L4.aid_renewgdp1	0.001	-27.688	427.704	-20,277.699	-7,081.962
	(0.17)	(1.06)	(0.02)	(0.87)	(0.48)
L5.aid_renewgdp1	-0.004	-60.008	-3,829.920	-44,093.088	-1,578.204
	(1.04)	(1.68)	(0.45)	(1.54)	(0.20)
lgdpc	0.519	0.222	0.389	0.532	0.343
	(5.17)**	(1.75)***	(3.77)**	(3.01)**	(2.80)**
renew1	-0.007	-0.003	-0.003	-0.007	-0.003
	(4.94)**	(1.14)	(1.07)	(3.83)**	(1.36)
investment_2	0.011	0.016	0.008	-0.000	0.011
	(5.62)**	(1.99)***	(1.10)	(0.01)	(2.03)*
industry	0.005	-0.017	-0.013	0.008	-0.005
	(1.53)	(1.35)	(1.20)	(0.47)	(0.68)
icrg_qog	0.123	0.078	0.923	0.071	0.609
	(0.40)	(0.14)	(1.30)	(0.13)	(0.98)
subprime	-0.013	-0.005	0.006	-0.006	-0.007
	(0.73)	(0.25)	(0.25)	(0.32)	(0.32)
oil_export			0.132		
			(1.26)		
new_indus			0.281		
			(0.77)		
imports				0.004	
				(1.63)	
fdi					-0.004
					(0.48)
_cons	-4.182	-1.479	-3.173	-4.214	-2.840
	(4.99)**	(1.56)	(4.33)**	(2.67)*	(2.77)**
N	293	299	299	279	291
Number of countries	53	53	53	51	52
AR(2)		0.74	0.84	0.78	0.89
Hansen test		0.16	0.33	0.45	0.40
R2	0.64				

*, **, and *** indicate significance at the 1%, 5% and 10% levels, respectively.

Table 2: Estimates of the relationship of climate finance with CO2 intensity

Econometric Method	OLS	Generalized Moment Method			
	CO2 intensity (kg per kg of oil per equivalent energy use)				
L.lco2_int	0.369	0.525	0.531	0.382	0.585
	(6.07)**	(4.13)**	(3.12)**	(3.99)**	(4.97)**
L.aid_renewgdp1	0.002	36.391	14.425	59.808	37.275
	(0.54)	(0.87)	(0.30)	(1.09)	(0.75)
L2.aid_renewgdp1	-0.013	-42.516	-45.569	-93.913	-34.472
	(2.55)*	(1.52)	(1.69)***	(2.44)*	(1.21)
L3.aid_renewgdp1	0.003	46.988	42.414	34.160	43.784
	(0.64)	(1.68)	(1.55)	(1.26)	(1.46)
L4.aid_renewgdp1	-0.002	-14.132	-19.114	-39.599	-10.691
	(0.33)	(0.49)	(0.66)	(0.96)	(0.35)
L5.aid_renewgdp1	-0.005	-21.531	-26.219	15.983	-30.697
	(1.09)	(0.68)	(1.12)	(0.37)	(1.08)
Lgdpc	0.214	0.288	0.279	0.285	0.260
	(2.52)*	(3.26)**	(2.75)**	(2.95)**	(3.06)**
renew1	-0.006	-0.004	-0.004	-0.006	-0.004
	(4.49)**	(2.43)*	(2.02)*	(3.43)**	(2.03)*
investment_2	0.011	0.008	0.009	0.001	0.011
	(5.97)**	(1.18)	(1.39)	(0.14)	(1.16)
industry	0.006	-0.000	0.005	0.018	-0.004
	(1.84)***	(0.04)	(0.40)	(1.71)***	(0.32)
icrg_qog	0.107	0.675	0.496	0.507	0.582
	(0.36)	(1.47)	(1.08)	(0.65)	(1.21)
subprime	-0.016	0.005	-0.003	-0.021	0.009
	(0.91)	(0.35)	(0.20)	(1.30)	(0.47)
oil_export			-0.165		
			(0.62)		
new_indus			-0.049		
			(0.22)		
imports				0.004	
				(1.38)	
Fdi					-0.006
					(0.63)
_cons	-1.709	-2.317	-2.246	-2.595	-2.045
	(2.38)*	(3.52)**	(2.99)**	(3.32)**	(3.09)**
N	290	296	296	277	288
Number of countries	53	53	53	51	52
AR(2)		0.99	0.91	0.49	0.80
Hansen test		0.50	0.23	0.26	0.51
R2	0.46				

*, **, and *** indicate significance at the 1%, 5% and 10% levels, respectively.

This could be explained by the fact that those countries are also preoccupied by their development process and therefore continue investing in activities that dampen the impact of climate aid for renewable energy on the overall CO2 emissions.

In contrast, the variable renew is significant and has a negative sign, implying that when renewable energy is implemented in a country, it does play a role in reducing CO2 emissions. Indeed, part of the fossil fuel energy used by the population is replaced by renewable energy, which is less polluting.

We now turn to the GMM results. The AR (2) and Hansen test are significant. We find the same variables as in the OLS estimate to be significant. We do not find any dummy variables to be significant, which means that oil-exporting countries do not display a very different pattern than other countries. The same is true for new industrialized countries, which seem to have not reached the path of development that supports the curbing of CO2 emissions by the use of innovative and less polluting technologies and production processes. The dummy for the subprime crisis is not significant, indicating that the decrease in climate aid because of the subprime crisis was not important enough to negatively impact the effect of climate aid on CO2 emissions.

In table 2, we now consider CO2 intensity as the dependent variable, defined as the quantity of CO2 emissions measured in kg of oil per equivalent energy use. This variable captures the amount of carbon dioxide emitted as a result of using one unit of energy in production. It is also a measure of the environmental impact of economic activities. The higher the CO2 intensity is, the more the country uses high-polluting energy sources. Therefore, a negative and significant impact of climate aid means the reduction of CO2 intensity and therefore the use of less-polluting sources of energy in the process of production.

As we did for the variable CO2 emissions, we ran a fixed effects OLS regression as a reference, taking CO2 intensity as the dependent variable. We find qualitatively the same results. In addition, concerning the GMM results, the AR (2) and Hansen test are significant and allow us to analyse our results. In particular, the lag of the dependent variable is significant with a positive sign, as are the variables for GDP per capita, investment and industry. This time, the industry variable, which appeared non-significant for CO2 emissions, displays a positive, significant coefficient. This indicates that an increase in the share of industry in GDP increases CO2 intensity. This result is consistent with the theory, as industrial production is relatively energy intensive.

The positive sign for other significant variables confirms our previous results. This confirms that the countries in our sample have not yet reached the threshold of using less CO2-intensive production processes. Again, when they invest in new technologies, they are more preoccupied by economic efficiency, at the expense of ecological efficiency.

Finally, the implementation of renewable energy sources results in less CO2 emission intensity in the production process, as less polluting energy is used. None of the dummies are significant, again confirming our previous results indicating no significant difference between new industrial countries and other developing countries and between oil exporting countries and non-oil exporting countries. The same is true for the subprime dummy, which indicates no significant impact of the subprime crisis on the effect of climate aid on the CO2 intensity of developing economies receiving the aid. We run the same regressions using dependent variables related to several sectors of cities, namely, CO2 emissions from residential buildings and commercial and public services, CO2 emissions from manufacturing industries and construction, and CO2 emissions from transport. However, apart from the lag of the dependent variables, no lag variables related to climate aid for renewable energy are significant. For the sake of brevity, the results are not presented here.

3.4. Robustness checks

For our robustness checks, we consider two additional explanatory variables (imports and foreign direct investment (FDI)) because, as mentioned by Kretschmer et al. (2011), they can be considered channels of technology. More precisely, foreign firms in the domestic market and openness to world markets exert a kind of pressure on domestic firms, such that they try to use new technology that enhances energy efficiency (Saggi (2002); Keller (2004) and Melitz and Ottaviano, (2008)). Imports are defined as a share of GDP (Hubler and Keller (2010)).

We successively test these variables and find no significant effect on CO2 emissions or CO2 intensity. This means that, at this stage, neither foreign direct investment in developing countries nor imports of manufactured goods from developed economies contribute to fostering the use of innovative ecological technologies that help in the reduction of CO2 emissions or CO2 intensity.

In an additional robustness test, we consider the price of diesel. This variable is available for 70 countries and is extracted from Bloomberg. A higher diesel price can be associated with a higher carbon tax in a country. Countries impose such a tax to increase the price of diesel and similar oil products to discourage their consumption. The results are displayed in Table 3 for CO2 emissions. Higher diesel prices negatively impact CO2 emissions, showing that a high diesel price (or similar oil product prices) is efficient in reducing CO2 emissions. As we use the diesel price as a proxy for the carbon tax, this result means that a higher carbon tax contributes to the reduction of CO2 emissions.

The literature on foreign aid mentions that the relationship between foreign aid and growth cannot be linear, Hansen and Tarp (2001). We test the quadratic term related to climate aid; we find that the second lag is significant, with a negative sign. This result means that there is a threshold beyond which climate aid, as expressed as a share of GDP, is effective in reducing CO2 emissions. Before this threshold, the amount of climate aid for renewable energy as a share of GDP does not help reduce CO2 emissions. The same regressions were made using CO2 intensity as the dependent variable, but the results for the variables of interest were not significant. We do not show the regressions for the sake of brevity.

Table 3: Additional robustness checks using CO_2 emissions

Dependent variable	CO2 emissions in metric tons per capita		
L.lco2_emi	0.502	L.lco2_emi	0.711
	(4.42)**		(4.76)**
L.aid_renewgdp1	95.334	L.aid_aid	14,214.681
	(1.83)		(1.61)
L2.aid_renewgdp1	-77.950	L2.aid_aid	-22,798.046
	(2.63)*		(2.39)*
L3.aid_renewgdp1	49.844	L3.aid_aid	8,532.887
	(1.67)		(0.85)
L4.aid_renewgdp1	-2.705	L4.aid_aid	-8,321.255
	(0.09)		(0.63)
L5.aid_renewgdp1	15.134	L5.aid_aid	319.184
	(0.62)		(0.04)
lgdpc	0.440	lgdpc	0.340
	(3.46)**		(2.84)**
renew1	-0.006	renew1	-0.003
	(2.82)**		(1.27)
investment_2	-0.002	investment_2	0.011
	(0.24)		(2.16)*
industry	0.005	industry	-0.006
	(0.52)		(0.81)
icrg_qog	-0.405	icrg_qog	0.599
	(0.68)		(1.00)
		subprime	-0.007
			(0.36)
diesel_price	-0.282		
	(2.71)*		
_cons	-2.774	_cons	-2.808
	(3.44)**		(2.89)**
N	113	N	299
Number of countries	31	Number of countries	53
AR(2)	0.69	AR(2)	0.88
Hansen test	0.87	Hansen test	0.43
Econometric method	GMM		GMM

4. Conclusion and policy implications

Several previous articles were interested in the role of foreign aid in the reduction of CO_2 emissions. However, the variable they considered was the total amount of foreign aid used to finance all development projects, irrespective of the type of projects. Development projects may encompass high-polluting projects as well as environmentally friendly projects. Therefore, the previous results were inconclusive. Indeed, the effects of polluting development projects and less polluting projects cancel each other out, which could explain the fact that previous results in the literature were non-significant or significant but negative (Kretschmer and al. (2011); Boly (2018); Bhattacharyya et al. (2016)). Development projects, which are devoted to the growth process, are subject to pollution issues as an externality. In contrast, our study considers sectoral foreign aid and especially official development assistance (ODA) and finds significant and consistent results.

This study sheds light on how foreign aid provided by developed nations helps developing nations adopt new technology in the production of renewable energy. Indeed, international discussions have led to the emergence of the idea that actions to fight global warming should be commonly undertaken by all nations. Thus, foreign aid could help in this sense by financing environmentally friendly development projects. Therefore, our article seeks to assess whether such an initiative has an impact on CO_2 emissions and the conditions through which the impact is significant. Our results differ from those of previous studies because of the data aggregation of the variable related to foreign aid.

Our results thus show that climate aid proxied by foreign aid for renewable energy negatively affects CO_2 emissions. However, much remains to be done. For recipient countries, although the reduction is significant, it is not persistent over time. This can be explained by the fact that developing countries are more preoccupied by their development process and therefore still favour projects that may be more polluting but offer a higher potential for development. Indeed, our regressions related to CO_2 intensity (which captures the environmental impact of economic activity) also indicate a transitory impact, coupled with the positive sign of coefficients related to GDP, investment and industry. At this stage, it is important for such countries to consider the environmental component of the development project to reduce the associated CO_2 emissions when asking for development aid. By doing so, developing countries will be able to target development projects that generate growth as well as environmental consciousness. Therefore, their legitimate desire to generate growth and enter the process of convergence with developed countries will not be hampered by environmental considerations.

For donors, there is a threshold amount of climate aid beyond which its impact is effective. This finding stresses the idea that donors should make an effort to reach this level and sustain it to have palpable effects on global warming. The statistics in the second section indicate that climate aid has dramatically increased over time, which shows the willingness of developed nations to work hand in hand with developing countries to address the issue of global warming. However, it is important that developed nations maintain this trend to have effective and persistent results on CO_2 emissions. Again, innovative ecological technologies, which are imported into developing countries through foreign direct investment (from developed countries that may be the same as the donor countries), do not yet play a significant role in reducing CO_2 emissions or CO_2 intensity. This indicates that there is still an effort to be made through the technological transfer of cleaner processes of production to less-developed countries (Honjo (1996); Yang and Nordhaus (2006) and Nowosielski et al. (2007)).

In addition, taxing plays a role in reducing the use of polluting energy sources, such as diesel. Indeed, our results indicate that when a carbon tax is applied, we can observe a negative and significant impact on CO_2 emissions. Such policies that consist of discouraging the use of more polluting sources of energy are efficient in fighting global warming. Finally, we do not find different patterns in the relationship between climate aid and CO_2 emissions, regardless of whether the country group concerns industrialized countries, oil exporting countries, or other developing countries. The level of industrialization or wealth in natural resources, such as oil, does not seem to make a difference for the nexus of climate aid and CO_2 reduction.

References

Arellano, M. and Bond, S., 1991." Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", Review of Economic Studies 58, pp. 277-297.

Arellano, M. and O. Bover , 1995. "Another Look at the Instrumental Variable Estimation of Error-Components Models". Journal of Econometrics 68, pp. 29-51.

Arvin B. M., P. Dabir-Alai, and B. Lew, 2006. "Does Foreign Aid Affect the Environment in Developing Economies?". Journal of Economic Development, 31(1), pp. 63–87.

Bhattacharyya, S. ; Intartaglia, M. and McKay, A.; 2016. "Does Climate Aid Affect Emissions? Evidence from a Global Dataset," CSAE Working Paper Series 2016-09, Centre for the Study of African Economies, University of Oxford.

Blundell, R., and S. Bond, 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models". Journal of Econometrics, 87(1), pp. 115–43.

Boly, M.; 2018. "CO2 mitigation in developing countries: the role of foreign aid". Working Papers 201801, CERDI.

Bond, S., Hoeffler, A., Temple, J., 2001. "GMM Estimation of Empirical Growth Models". Economic Papers, W21. Nuffield College, University of Oxford.

Boone, P. ,1996. "Politics and the Effectiveness of Foreign Aid". European Economic Review, 40(2), pp. 289–329.

Burnside, C., and D. Dollar, 2000. "Aid, Policies, and Growth". American Economic Review, 90(4),pp. 847–68.

EDGAR Report, 2019. European Commission. https://edgar.jrc.ec.europa.eu

Esposito L., Gatti E. G., and Mastromatteo G., 2019. Sustainable finance, the good, the bad and the ugly: a critical assessment of the EU institutional framework for the green transition.

Hansen, H., and F. Tarp ,2001. "Aid and Growth Regressions". Journal of Development Economics, 64(2), pp. 547–70.

Honjo, K., 1996. "R&D for technology to solve global warming". Journal of Material processing technology, 59 (3), pp. 218-220.

Hübler, M. and A. Keller, 2010. "Energy Savings via FDI? Empirical Evidence from Developing Countries". Environment and Development Economics 15(1), pp. 59-80.

IPCC, 2014. 'Summary for Policymakers', in: O. Edenhofer et al. (eds), Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment 23 Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC, 2018. Global Warming of 1.5◦C. Technical report, Intergovernmental Panel on Climate Change.

Jorgenson, A. K., 2007. "Does Foreign investment harm the air we breathe and the water we drink? A cross-national study of carbon dioxide emissions and organic water pollution in less-developed countries, 1975-2000." Organization and Environment, 20 (2), pp. 137-156.

Kablan, S., 2013. "Foreign Aid, Green Cities and Buildings." WIDER Working Paper Series 048, World Institute for Development Economic Research (UNU-WIDER).

Keller, W. , 2004. "International technology diffusion". Journal of economic literature, 42(3), pp. 752-82.

Kretschmer, B. M. Hubler, and P. Nunnenkamp, 2011. "Does Foreign Aid Reduce Energy and Carbon Intensities of Developing Economies?". Journal of International Development, 25(1), pp. 67-91.

Le Quéré, C., Korsbakken, J. I., Wilson, C., Tosun, J., Andrew, R., Andres, R. J., Canadell, J. G., Jordan, A., Peters, G. P., and van Vuuren, D. P., 2019, Drivers of declining CO2 emissions in 18 developed economies, Global Carbon Budget Report, pp. 213–217.

Lim, S., Menaldo, V., and Prakash, A. , 2015. "Foreign aid, economic globalization, and Pollution". Policy Sciences, 48(2), pp.181–205.

McNicoll, L., R. Jachnik, G. Montmasson-Clair and S. Mudombi, 2017. Estimating Publicly-Mobilised Private Finance for Climate Action : A South African Case Study', OECD Environment Working Papers, No. 125, OECD Publishing, Paris, https://dx.doi.org/10.1787/a606277c-en.

Melitz, M.J., Ottaviano, G.I.P., 2008. "Market size, trade and productivity". The Review of economic studies, 75(1), pp.295-316.

Nickell, S., 1981, "Biases in Dynamic Models with Fixed Effects". Econometrica, 49(6), pp. 1417-26.

Nowosielski, R.; Babilas, R. and Pilarczyk, W., 2007. Sustainable technology as a basis of cleaner production, 20 (1-2), pp. 527-30.

OECD, 2015. Climate Finance in 2013-14 and the USD 100 billion Goal: A Report by the OECD in Collaboration with Climate Policy Initiative, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264249424-en; OECD (2016), 2020 Projections of Climate Finance Towards the USD 100 Billion Goal: Technical Note, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264274204-en

OECD, 2018. 'Implementing the Paris Agreement: Remaining Challenges and the Role of the OECD'.

OECD, 2019. Climate Finance Provided and Mobilised by Developed Countries in 2013-1.
Polycarp, C., L. H. Brown and X. Fu-Bertaux (2013), "Mobilizing Climate Investment: The Role of International Climate Finance in Creating Readiness for Scaled-up Low-Carbon Energy", World Resources Institute, www.wri.org/publication/mobilizing-climate-investment.

Saggi, K., 2002,."Trade, Foreign direct Investment and international technology transfer: a survey".World Bank Research Observer, 17(2), pp.191-235.

Standard & Poor's, 2014. How Climate Change Can Impact Sovereign Ratings, Standard &Poor's Ratings Services.

Yang, Z. and Nordhaus, W. D., 2006. "Magnitude and direction of technological transfers for mitigating GHG emissions." Energy Economics, 28, pp. 730-41.

Ziervogel, G. ; New M.; Archer van Garderen E., Midgley, G.; Taylor A., Hamann, A.; Stuart-Hill S.; Myers J.; Warburton, M.; 2014. "Climate Change Impacts and Adaptation in South Africa." Wiley Interdisciplinary Reviews: Climate Change, 5 (5), pp. 605–620,

Zingel, J., 2011. "Climate Change Financing and Aid Effectiveness: South African Country Analysis." Organisation for Economic Co-operation and Development and African Development Bank, Paris and Tunis, www.oecd.org/dac/environment-development/48458419.pdf.