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Research article

Climate bonds: Are they invested efficiently?

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ABSTRACT

Achieving a Net-Zero goal is heavily reliant on transitioning to green methods, making it a top priority. Our research, which used the Generalized Least Squares (GLS) panel method, found that each Macro-region should invest at least 2% more per capita annually in Climate Bonds, a type of green bond. Although some studies have questioned the effectiveness of Climate Bonds, our focus is on their efficient use in countries that produce more fossil fuels.

Our findings show that globally, a) Climate Bonds are underutilized in areas with higher per capita use of fossil fuels, and b) High-income countries are gradually reducing their reliance on fossil fuels, while low-income countries have always used very little (with a forecast of future growth). Allocating financial resources in the form of Climate Bonds for the green transition should consider per capita use of fossil fuels, as well as the heterogeneity of population growth and different Macro-Regional economic development. Developing countries, with their large populations, will require more financial resources for an ethically acceptable green transition in the future.

1. Introduction

Achieving the wide and crucial goals of the Ecological Transition demands an unparalleled commitment of resources from both the public and private sectors. This paper specifically focuses on Climate Bonds, a type of green bond. In a recent study by Arora-Jonsson and Gurung (2023), the authors highlight the importance of considering human dimensions in economic issues, particularly in global environmental governance.

Our paper offers a foundation for reflecting on how financial resources are allocated. It's important to note that there are diverse realities worldwide, and even if some regions consume less fossil fuel per capita, they will need to manage emissions in the future. Our statistical analysis reveals that regions with higher per capita use of fossil fuels underutilize Climate Bonds. Therefore, macro-regions with higher populations must invest at least 2% more per capita in Climate Bonds annually.

The transition is arduous and requires a global mindset shift. Funding for fossil fuel subsidies has been conspicuous for some years as documented in Coady et al. (2017). Estimated subsidies are $4.9 trillion worldwide in 2013 and $5.3 trillion in 2015 (6.5% of global GDP in both years). However, even the subsidies have not been and are not enough. In our work, we analyze Climate Bonds which are part of the green financial market aimed at reducing greenhouse gases, and they can be regulated by policymakers.

Van Renssen (2014) claims that when it comes to investments, the smart bet may be on clean energy and low-carbon infrastructure. We know from economic theory that entrepreneurs invest by maximizing their profit function. So how is it possible to direct investments in the direction useful for collective well-being? Global demands on the green transition are very prominent. The UN Environment United Nations Environment Programme (2022) states "Net-zero" commitments must be backed by credible action. Where Net-zero consists of cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions absorption from the atmosphere, by oceans and forests for instance. This goal is important at odds with the Paris Agreement (December 2015) to keep global warming no more than 1.5 °C to reach Net-zero by 2050. The common approach in analyzing fossil fuel emissions almost completely ignores the per capita population. In the present work, the coefficient representing the investment in Climate Bonds is negative with respect to the per capita use of fossil fuels. This indicates the extreme importance of population density in the various regions of the world alongside environmental policies.

The actions to reach net zero by 2050 are the greatest challenges humankind is facing and involves the energy sector as the source of around three-quarters of greenhouse gas emissions. To change and be successful in the green transition, it is essential to coordinate economic flows and financial instruments such as Climate Bonds, paying attention

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to the growth in the number of inhabitants and the speed with which many emerging countries are growing.

A study linking non-renewable energy consumption and urbanization is Salim and Shafiei (2014). They analyze the impact of urbanization on renewable and non-renewable energy consumption in OECD countries finding that total population and urbanization positively influence non-renewable energy consumption (although we believe it is not a rule). Population density hurts non-renewable energy consumption. *We take an extra step by analyzing whether climate investments consider population density. Our empirical analysis specifically takes into account* per capita *consumption.* Our empirical research finds that not enough resources are invested in less developed countries to convert fossil fuel use to clean sources and the Net Zero objective involves a national political strategy.

Cui and Huang (2018) find that the decision of the United States to withdraw from climate finance will significantly increase the burden for other donors. While the United States is the country with the greatest consumption of fossil fuels (as we will see shortly). Climate Bonds Initiative (launched at COP15 in Copenhagen) is an international organization working to mobilize global capital for climate action. Great despondency is evidenced by Palmer (2022). He highlights that the current level of investment in renewable energy projects and energy efficiency projects is insufficient to achieve the goals established by the international climate agreements. The author sees a serious issue with greenwashing. In the same line of study, there are the McKinsey Global Institute (January 2022) papers. The topic of greenwashing deserves a separate paper as the problem is severe. It is important to analyze credit allocation policies and carefully study incentives for firms to act responsibly, especially in certain macro-regions.

Schumacher (2020) advances the thorny problem of independent judgment in green classifications and conflicts of interest. Haszeldine (2009), worries about the problem over 14 years ago and writes there is a lamentable lack of financial commitment. These problems will be empirically and regionally studied, after having understood, in the present work, how funds for the climate transitions are allocated in the large Macro-Regions. As soon as it has been established that this allocation is not geographically efficient, we can consider the problems raised (financing difficulties and the use of green projects alternative to fossil fuels) as reinforcing elements that require greater commitment of world policies and their coordination. Coordination is key, even if regions are heterogeneous, it is important to do more to give access to funding sources (climate bonds) in a flexible way and possibly with consideration of the least developed countries where the cost of funding should be decreased.

One argument could be that governments tax or subsidize fossil fuels, however Mahdavi et al. (2022) find that is far from optimal and therefore the financial instruments route remains the most feasible by policy makers. In their empirical analysis, it is shown that these taxes and subsidies appear to be driven by the same fiscal conditions that determine other types of taxes.

The study of the optimal allocation of funds is implicit in the work of Böhringer and Löschel (2008). The authors observe that low-risk developing countries attract higher project volumes and benefit from higher effective prices per emission credit compared to a reference scenario without risk, the opposite applies to high-risk countries. They show, empirically, how risk considerations affect the economic implications of emission crediting. Dorband et al. (2019) assess the expected incidence of moderate carbon price increases for different income groups in 87 mostly low- and middle-income countries. They find that carbon pricing tends to be regressive in countries with relatively higher income. Suggest that mitigating climate change and reducing economic inequality are not mutually exclusive, even in low- and middle-income countries. In line with our contribution, low-income countries facing the Ecological Transition must be accompanied by financial tools because their population growth is (Han and Chatterjee, 1997), and will be, increasingly sustained.

This work is of primary importance for the decisions of all policymakers such as, for example, Central Banks (Campiglio et al., 2018). A relevant contribution of the work is to consider the difference in the use of fossil fuels by controlling the per capita income of the different countries. Dong et al. (2020) which, however, deal with renewable energies (which is not the purpose of this work) complains that significant difference in the emission–renewables nexus across countries with different income levels is frequently ignored. This paper demonstrates that even fossil fuel emissions per capita and the investment to remedy them do not consider the income of the macro-region. Some works, such as Chen (2011) consider the problem of reducing emissions for a single country, for example, China, and not the comparison between different regions of the world. Instead, comparing different geographic areas and, especially their population density, is crucial.

The rest of the paper is organized as follows. Section II introduces the motivation of the work and the Macro-Regions subject of analysis. Section III presents the methodology. Although the dataset is small and compact (we use aggregate yearly data), the results are econometrically robust. Section IV introduces Climate Bonds as a financial instrument. We conclude in section V by suggesting useful developments of the work: how risky are sustainable investments and forecasting the possibility of reaching net-zero within the imposed deadlines.

2. Motivation

The objectives sanctioned by the UN Environment Program (2022) state “Net-zero” are very ambitious and global in scope. We are probably facing the greatest revolution that will change our lives and those of future generations. It is vital to move in a coordinated way. As stated in Streeten (1991) the necessary conditions for a working international order concerned with development. The work is significant because it confirms, once again, how cooperation must be global. The ecological transition, in addition to being a cultural issue, is the way we invest our financial resources. There are now innumerable financial instruments that are called “green bonds”, therefore, in order not to get confused and to make the analysis clean, this work uses uniform and well-defined data: the Climate Bonds. The main question is: are we using Climate Bonds efficiently? That is, where the per capita use of fossil fuels is higher.

The question of the paper is: are Climate Bonds used to decrease fossil fuel emissions? This research requires comparing different geographic areas. We have tried to cover the whole world. There are obviously many heterogeneous situations within Macro-Regions and between Macro-Regions, however, we believe that the result is clear. *There is no optimal allocation of Climate Bonds.* This is important for policymakers. Unfortunately, one of the main problems is that there is no coordination at the level of global or national institutions. Also, a lot comes from different mentalities some of which are implemented by the European Union (The European Commission proposed the Net-Zero Industry Act (NZIA) on March 16, 2023).

The analysis covers five Macro-Regions: Africa, Asia-Pacific, Europe, Latin America, and North America in line with how data on Green Bonds and fossil fuels are classified both by the “Climate Bond Initiative” and by the World Bank. The variable used is the Fossil fuels per capita (kWh), Fossil fuels (TWh), the GDP per capita in dollars, and Climate Bonds in bn$. We highlight consumption by region according to income level. Fig. 1 shows that high-income countries are decreasing the consumption of fossil fuel only recently, while lower-income countries are increasing their consumption since the eighties, with a timid slowdown in recent years. Since the 1960s, high-income macro-regions have maintained a sustained use of fossil fuels.

Table 1 shows three different historical periods with the related consumption per person in some countries. Interestingly, both total and per capita consumption for India has always been lower than that of more developed countries. India has 1.408 billion inhabitants in 2021. A comparison with the United States is very useful: they are 331.9 million.

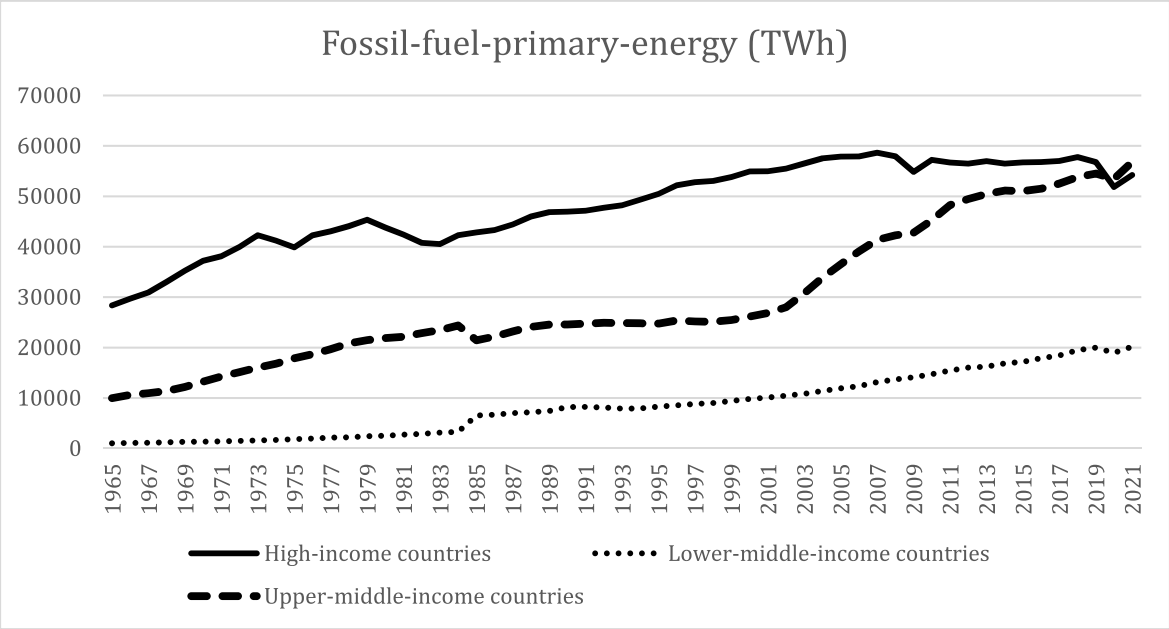

Fig. 1. Fossil fuel consumption: source World Bank.

Table 1
Fossil fuel consumption per capita Fossil fuel consumption per capita is measured as the average consumption of energy from coal, oil, and gas per person.

1973		1980		2021	
United States	92,635 kW h	United States	85,529 kW h	United States	62,365 kW h
Germany	49,634 kW h	Australia	54,616 kW h	Australia	53,369 kW h
Australia	46,765 kW h	Germany	51,665 kW h	Germany	31,834 kW h
United Kingdom	45,869 kW h	Europe	43,908 kW h	Europe	30,030 kW h
Europe	39,627 kW h	United Kingdom	40,201 kW h	China	25,403 kW h
France	38,370 kW h	France	35,803 kW h	United Kingdom	22,610 kW h
South Africa	20,576 kW h	South Africa.	21,821 kW h	South Africa	22,034 kW h
China	3,491 kW h	China	4,739 kW h	France	20,192 kW h
India	1,251 kW h	India	1,504 kW h	India	6,626 kW h

The speed of demographic growth is also important: stable for developed countries and very sustained for countries such as India (Gupta et al., 2019) and China. However, just India and China invest less in Climate Bonds in relation to their production of greenhouse gases. As per Table 2, Europe is the first investor: the EU countries with legally binding agreements so far are Sweden, the UK, France, Denmark, New Zealand, and Hungary. Sweden set itself up for carbon neutrality by 2045 and ne of their goals is to reach emission reductions by 70% (from 2010) in the area of ground transportation by 2030. North America is not equally committed to investing in climate bonds. Very briefly, Europe is the geographical area most sensitive to the climate problem and is investing conspicuous financial resources. While Table 1 demonstrates that the United States (included in the term "North America") has always been in first place in fossil fuel consumption per capita.

It is interesting to highlights the work of Yu et al. (2022). They state that low-carbon transition involves achieving coordinated development between economic development and carbon reduction. This means achieve the Net-Zero without slowing down or compromise the development process. The paper of Yu et al. (2022) finds that the impact of energy consumption per capita is negligible: they investigate the country-level low-carbon transition efforts across 29 OECD countries in the period 1992–2018. The reduction in carbon emission intensity is primarily attributed to the changes in economic development and energy intensity.

Having documented these consumptions, the UN Environment Program (2022) states "Net-zero" commitments must be backed by credible action. A viable way is to divert finances and investments towards the green industry, through Climate or Green Bonds (Table 2). The table demonstrates low investment precisely in countries such as Africa and Asia-Pacific countries which have high population growth prospects, and which are increasing their level of industrial development.

Since the ecological transition is a long-term program, even if we see that the most polluting countries are those that issue the most Climate

Table 2
Total Climate Bonds in bn$.

Climate Bonds Initiative - Region Green | Total | Amount Issued | Global									
YEAR	2014	2015	2016	2017	2018	2019	2020	2021	2022
Region									
Africa	0.1		0.2	0.3	0.2	0.9	1.2	0.4	0.3
Asia-Pacific	1.6	3.6	26.5	35.5	48.5	66.9	52.7	143.3	133.4
Europe	17.9	19.6	25.8	60.6	67.1	120.3	162.9	294.3	228.6
Latin America	0.2	1.1	1.6	4	2.4	5.2	10.9	9.1	3.1
North America	7.4	12.8	20.8	48.7	38.9	62.7	61.5	103.9	76.6
Supranational	9.4	8.4	10.2	9.5	12.1	13.1	13.8	31.4	45.1

Bonds, through rigorous statistical analysis we study whether this is sufficient or if instead we should take into account that the less developed regions will urgently need of energy sources, and in this case, of the green type instead of fossil fuels. However, the green transition is a dynamic process. For now, we can document that very polluting Macro-Regions do not invest enough in Climate Bonds. However, Macro-Areas such as North America, while investing in Climate Bonds, should invest more. Also, because their industrialization process is very vast, and they certainly have the financial resources to invest in Climate Bonds in proportion to their size. Deutch (2020) to the question "is it possible for the U.S. and the world to achieve the net zero 2050 goal?" he replies "Unfortunately, the answer to both questions is *no*." Moreover, he continues stating that The United Nation's Framework Convention on Climate Change (UNFCC), the governance structure available for global climate policy and programs, has not been given the authority and responsibility for planning and implementing a global net zero program.

An opposite opinion is expressed in the elaborate work of Seto et al. (2021). They claim that it is possible, although difficult, to get to or near net-zero carbon, but this requires systemic transformation.

In our paper we demonstrate that the Net-Zero goal requires the investment of resources. Although we analyze the Climate Bonds (due to lack of other data), greater investment by the richest countries would be desirable. While it must be the policy maker who decides how to meet developing countries and how to talk about the issue with the emerging ones. We don't have a crystal ball, but it is certain that by investing and collaborating we can improve the situation. Europe's average per capita income is lower than that of the United States, yet environmental sensitivity is higher. This demonstrates once again that it is a matter of responsibility and mentality which then moves capital and financial resources.

3. What are climate bonds

Climate Bonds are fixed-income financial instruments issued to raise finance for climate change. Like normal bonds, Climate Bonds can be issued by banks, corporations, governments, and other institutions. The issuing entity guarantees to repay the bond over a certain period, plus either a fixed or variable rate of return. The climate solutions that they finance are related mainly to the greenhouse gas emission reduction. For this reason, they are very important in the Net-Zero process. The Climate Bonds Initiative works on a number of country specific Market Development programs and regional projects. A well-developed program is the project with the European Commission and involves How best to use the EU Budget to mobilize low carbon investments (The Climate Pact Community).

The Climate Bond initiative involves developing a Climate Bonds private placement market in Europe, Growing Green Bonds in China, Corporate Green Bonds in India, and other Climate projects around the World. India's low carbon economic transition requires investment that the Indian Government cannot afford alone. The development of bond markets is a policy goal of the Government vital to tapping domestic savings.

Climate Bonds has a Taxonomy that is a guide to climate aligned assets and projects. It is a tool for issuers, investorsm and governments to help them understand what the key investments are that will deliver a low carbon economy. The Taxonomy is consistent with the goals of the Paris Agreement. Climate Bonds Taxonomy was released for the first time in 2013, it is regularly updated based on the latest climate science, emergence of new technologies and sector specific Criteria. The priority is given to projects that are aligned with a net zero by 2050 trajectory. The data confirms the subsequent analysis of the paper regarding Europe. Financial companies have shown great sensitivity, contributing 29% of volumes in 2022, while 25% came from non-financial companies. As our estimates confirm, European companies have been responsible for almost half of the private sector's green emissions, the two largest issuers being German commercial bank Helaba with $5.2 billion and Denmark's energy multinational Orsted with 4 billion dollars.

Just under 20% of green emissions in 2022 was done by the government, which as the only type of issuer recorded an increase compared to 2021 (+6%) led by the European Union which is in strict agreement with the emission of Climate bonds.

4. Methodology

The statistical methodology employs Generalized Last Squares (GLS) panel regressions with random effects. The GLS is typically used for estimating the unknown parameters in a model when there is a certain degree of correlation between the residuals in the regression model. The dataset is yearly and spans from 2014 (the period from which we have numbers on Climate Bonds for all world regions) to 2022. Even if there is not much data available, we are still able to obtain a statistically consistent estimate. It is shown that regressions with few data if they have an acceptable R squared and the coefficients are significant, then the results are to be considered reliable (see Hsiao, 2022). We try also with fixed effect and the results are quite robust.

Econometric estimation can demonstrate the *trend*. While the more industrialized countries seem to invest heavily in climate bonds, at a marginal level, the developing countries are lacking in this aspect. However, Macro-Regions such as North America do not invest enough in proportion to their per capita emissions. This result is predictable because it has already been seen in Table 2.

To dissect the results of the regressions that we will soon see regarding the Macro-Regions Africa, Asia-Pacific, Europe, Latin America, and North America, we analyze the heterogeneity among them. Africa has on average over year a consumption per capita of 3.76 kW h and the investment in Climate Bonds is only 0.45 bn$. North America has on average over year a consumption per capita of 45.53 kW h and the investment in Climate Bonds is 48.14 bn$. Interesting is the Asia Region the average over year consumption per capita is 15.72 kW h and the investment in Climate Bonds is 56.89 bn$. Although the group of Asian countries' per capita consumption of fossil fuels is lower than that of North America, their annual investment in climate bonds is higher. However, probably also for cultural reasons, Asian countries take global emissions into account, aware of being a very populous and therefore polluting area.

The country that invests most in Climate Bonds is Europe, with an annual average of 110.78 bn$ and an average fossil fuels consumption per year of 30.72 kW h.

Tables 3 and 4 demonstrate that there is a negative link between fossil fuels and the amount of Climate Bonds: bonds that specifically finance projects that reduce carbon emissions or alleviate the effects of climate change. The result is significant (p-statistics equal to zero) when the data is per capita. The sign is always negative also for total emissions, but the coefficient is not statistically significant. Table 3 is in line with the Yu et al. (2022) results: the impact of energy consumption per capita is negligible. To reinforce this result, the coefficient in Table 3 indicates that the per capita consumption of fossil fuels decreases the investment in Climate Bonds by about 2% (−0.021). The interpretation is to be found in the fact that emerging and developing countries have a rapid population growth which, while not consuming many fossil fuels individually, have still many inhabitants and the financial system does not arrive sufficiently to support the transition by objective Net-Zero.

Table 3 which reports the regression per capita, in addition to having the coefficient of investments in Climate Bonds significant, demonstrates a very high R squared among the group. The coefficient on per capita income is also statistically significant. Therefore, the statements are confirmed: the investment in Climate Bonds is not used where there is a need to reduce fossil fuel emissions. However, we don't want to be alarming, these regressions are a static picture of the current situation. Countries that are growing industrially will then have the financial resources to afford the green transition. At this time, they can also enjoy

Table 3
GLS estimation between fossil fuels emission per capita and Climate Bond.

Random-effects GLS regression

Group variable: 5 macro regions

R-sq:

within = 0.0765

between = 0.9682

overall = 0.9619

Obs per group:

min = 7

avg = 7.8

max = 8

Wald chi2(2) = 61.65

corr(u_i, X) = 0 (assumed)

Prob > chi2 = 0.0000

Fossil fuels per capita Dependent variable (Y)	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Climate Bonds	**-.0206822**	**.0048733**	**-4.24**	**0.000**	-.0302337	-.0111306
Gdp per capita	.0007021	.000091	7.72	0.000	.0005237	.0008804
cons	1.877287	3.143019	0.60	0.550	-4.282917	8.037491

sigma_u | 3.6879415

sigma_e | 1.1968963

rho | .90470859 (fraction of variance due to u_i)

spillovers from the countries they trade with and have relationships of various kinds. The world is currently moving faster and our analyzes will change (hopefully for the better).

An obstacle that could have determined the negative value of the investment coefficient in Climate Bonds can be found in the work of Kling et al. (2021). They theoretically, shows how climate vulnerability could affect firms' cost of capital and access to finance. Ng and Tao (2016) study the cause of the funding gap in Asia and proposes the use of bond financing to bridge the funding gap. They value three fixed-income instruments, namely corporate bonds denominated in local currency (LCY), asset-backed project bonds and financial green bonds. Their results demonstrate that the use of green bonds is the most effective as long as the financial sector is better developed in this sense and costs are low. We could have included additional variables in our analysis, but this is not functional to our initial question: are Climate Bonds used where there is greater need? Unfortunately, we find that there is not correspondence with the objectives of these financial instruments. Surely the analysis must be repeated in the coming years to probe the changes. Indeed, the transition is a dynamic process. We can already observe how Africa and Latin America, but also Europe itself, have been moving rapidly in recent years and, despite the COVID-19, there has been a recovery. Moreover, a curious and interesting work of Romero and Gramkow (2021) provides evidence that economic complexity contributes to reduce greenhouse gas emission intensity as well as per capita emissions because it is associated with high value-added product and production methodology. Their results can be translated into policy indications. Although it is not trivial, it is always connected to creating value and abandoning production methods from the old industrial revolution.

Table 4 shows GLS estimation between TOTAL fossil fuels emission and Climate Bond. While the regression coefficient for Climate Bonds is not significant, it is negative. The estimate is not as robust as that in Table 3, however this makes sense. It means that per capita emissions are undoubtedly the most important variable for obtaining results with Climate Bonds in terms of reduction of greenhouse gases. The message is that population density must be taken into consideration. Table 4 has practically zero R squared. Again, we confirm that the correct estimates are per capita, and that Table 3 provides the statistically relevant results. We have also reported Table 4 only to demonstrate that the variable to be used is the per capita emission.

5. Conclusion and policy implications

The data relating Climate Bonds and emissions from fossil fuels demonstrate that there is a certain per capita effect: as the population growth in tandem with greenhouse gas emissions, the financial instruments to stem the problem are used less. There is an effect due to income that will probably increase in the coming years: where the population grows more it does not invest, or it invests less in Climate Bonds, compared to already developed countries. A particular situation is represented by North America which has always recorded the largest quantity of fossil fuels emissions yet does not invest as much as it should in Climate Bonds.

North America, of which the United States is the spokesperson, has never been very convinced of the Net-zero objective: Deutch, J. (2020) replies that it will not be achieved within the required time frame. Of a different opinion are Seto et al. (2021), they argue that it is possible under several efforts. Since as early as January–February 1994, American scientists have expressed wildly divergent views on climate change (Nordhaus, 1994). Recently, the positions have changed and Mohaddes et al. (2023) admit the adverse effects that climate change has on economic activity and employment. Furthermore, concern for the future emerges in the paper.

Europe is the most virtuous being the Macro-Area that invests most

Table 4
GLS estimation between TOTAL fossil fuels emission and Climate Bond.

Random-effects GLS regression

Group variable: 5 macro regions

R-sq:
within = 0.2240
between = 0.0010
overall = 0.0001

Obs per group:
min = 7
avg = 7.8
max = 8

Wald chi2(2) = 8.90
Prob > chi2 = 0.0117

corr(u_i, X) = 0 (assumed)

Total Fossil fuels Dependent variable (Y)	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Climate bonds	**-4.916104**	**6.332714**	**-0.78**	**0.438**	-17.328	7.495788
Gdp per capita	.6159004	.2274062	2.71	0.007	.1701924	1.061608
cons	8581.245	16196.64	0.53	0.596	-23163.58	40326.07

sigma_u | 33648.98
sigma_e | 1431.1332
rho | .99819436 (fraction of variance due to u_i)

in Climate Bonds. This should not be surprising as European culture has always been very sensitive to the environment. This difference between countries is still in its infancy. As Fig. 1 of this paper demonstrates, it is very likely that low-income countries with higher population will growth (Jeffries, 2016) and may divert financial resources less into sustainable instruments and more into "traditional brown economy". While the results of developing or emerging countries are not surprising, the situation in North America is paradoxical. The data shows the Macro-Area with the highest per capita consumption of fossil fuels, but it is certainly not in first place in the use of Climate Bonds. As we have seen, the major investors in Climate Bonds are European countries.

These results suggest policy makers to issue alternatives feasible both in terms of time and financially to give access to the poorest and most populous countries. Nawaz et al. (2021) highlights that green finance is linked to investment risk, particularly in emerging and developing economies. In our view, the risk of green financial instruments is high in all countries, and this will be the subject of future research. For now, we can suggest an adequate education on sustainable finance. Such education still very lacking. To achieve the ambitious goals of The UN Environment Program (2022) with the "Net-zero" it is essential to act jointly at a global level. As we have seen in this work, this means accompanying developing countries towards more conscious growth and allocating more funds so as not to put coal-dependent countries in difficulty. The high population density and the low income of these countries do not allow them an ecological transition without the support of the more developed countries. Fadly (2019) examines the time duration to private sector investment in renewable energy projects in 134 developing and middle-income countries for the (1990–2012) and shows significant negative effects of fossil fuel consumption and fuel rent on investment likelihood. The work is significant because it confirms, once again, how cooperation must be global.

Credit author statement

To Journal of Environmental Management Editorial Board.

I, Marcella Lucchetta, am the sole author and responsible for the entire work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Arora-Jonsson, S., Gurung, J., 2023. World development perspectives. World Dev. 29, 100474.

Böhringer, C., Löschel, A., 2008. Climate policy-induced investments in developing countries: the implications of investment risks. World Econ. 31 (3), 367–392.
Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., Tanaka, M., 2018. Climate change challenges for central banks and financial regulators. Nat. Clim. Change 8 (6), 462–468.
Chen, S., 2011. The abatement of carbon dioxide intensity in China: factors decomposition and policy implications. World Econ. 34 (7), 1148–1167.
Coady, D., Parry, I., Sears, L., Shang, B., 2017. How large are global fossil fuel subsidies? World Dev. 91, 11–27.
Cui, L., Huang, Y., 2018. Exploring the schemes for green climate fund financing: international lessons. World Dev. 101, 173–187.
Deutch, J., 2020. Is net zero carbon 2050 possible? Joule 4 (11), 2237–2240.
Dong, K., Dong, X., Jiang, Q., 2020. How renewable energy consumption lower global CO2 emissions? Evidence from countries with different income levels. World Econ. 43 (6), 1665–1698.
Dorband, I.I., Jakob, M., Kalkuhl, M., Steckel, J.C., 2019. Poverty and distributional effects of carbon pricing in low-and middle-income countries–A global comparative analysis. World Dev. 115, 246–257.
Fadly, D., 2019. Low-carbon transition: private sector investment in renewable energy projects in developing countries. World Dev. 122, 552–569.
Gupta, D., Ghersi, F., Vishwanathan, S.S., Garg, A., 2019. Achieving sustainable development in India along low carbon pathways: macroeconomic assessment. World Dev. 123, 104623.
Han, X., Chatterjee, L., 1997. Impacts of growth and structural change on CO2 emissions of developing countries. World Dev. 25 (3), 395–407.
Haszeldine, R.S., 2009. Carbon capture and storage: how green can black be? Science 325 (5948), 1647–1652.
Hsiao, C., 2022. Analysis of Panel Data (No. 64). Cambridge university press.
Jeffries, E., 2016. Freeing fossil fuels. Nat. Clim. Change 6 (2), 125–126.
Kling, G., Volz, U., Murinde, V., Ayas, S., 2021. The impact of climate vulnerability on firms' cost of capital and access to finance. World Dev. 137, 105131.
Mahdavi, P., Martinez-Alvarez, C.B., Ross, M.L., 2022. Why do governments tax or subsidize fossil fuels? J. Polit. 84 (4), 2123–2139.
McKinsey Global Institute, 2022. The Net Zero Transition: what it Would Cost, what it Could Bring". McKinsey & Company Report.
Mohaddes, K., Ng, R.N., Pesaran, M.H., Raissi, M., Yang, J.C., 2023. Climate change and economic activity: evidence from US states. Oxford Open Economics 2.
Nawaz, M.A., Seshadri, U., Kumar, P., Aqdas, R., Patwary, A.K., Riaz, M., 2021. Nexus between green finance and climate change mitigation in N-11 and BRICS countries: empirical estimation through difference in differences (DID) approach. Environ. Sci. Pollut. Control Ser. 28, 6504–6519.
Ng, T.H., Tao, J.Y., 2016. Bond financing for renewable energy in Asia. Energy Pol. 95, 509–517.
Nordhaus, W.D., 1994. Expert opinion on climatic change. Am. Sci. 82 (1), 45–51.
Palmer, L., 2022. Green energy financing. Nat. Sustain. 5 (11), 910–911.
Romero, J.P., Gramkow, C., 2021. Economic complexity and greenhouse gas emissions. World Dev. 139, 105317.
Salim, R.A., Shafiei, S., 2014. Urbanization and renewable and non-renewable energy consumption in OECD countries: an empirical analysis. Econ. Modell. 38, 581–591.
Schumacher, K., 2020. Green investments need global standards and independent scientific review. Nature 584 (7822), 524–525.
Seto, K.C., Churkina, G., Hsu, A., Keller, M., Newman, P.W., Qin, B., Ramaswami, A., 2021. From low-to net-zero carbon cities: the next global agenda. Annu. Rev. Environ. Resour. 46, 377–415.
Streeten, P., 1991. Global prospects in an interdependent world. World Dev. 19 (1), 123–133.
United Nations Environment Programme, 2022. The Closing Window: climate crisis calls for rapid transformation of societiesEmissions Gap Report 2022. Job number: DEW/2477/NA.
Van Renssen, S., 2014. Investors take charge of climate policy. Nat. Clim. Change 4 (4), 241–242.
Yu, B., Fang, D., Kleit, A.N., Xiao, K., 2022. Exploring the driving mechanism and the evolution of the low-carbon economy transition: lessons from OECD developed countries. World Econ. 45 (9), 2766–2795.