European journal of volunteering and community-based projects Vol.1, No 2; 2024
ISSN: 2724-0592 E-ISSN: 2724-1947
Published by Odv Casa Arcobaleno

# Reduction of Environmental Pollution in Africa: ICT and Greenhouse Emissions

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**Abstract:** The level of carbon dioxide (CO2) emissions is under constant scrutiny by many scholars. This is due to the level of growth of the world population and of the Information and Communication Technologies (ICT) sector and consequently to the ever-increasing global economic development, which contribute significantly to the increase in energy consumption and the consequent increase in emissions of CO2. The aim of this study is to examine how CO2 emissions grow with population growth and whether this can be related to industrialization. To achieve this objective, an analysis was conducted on panel data based on Africa over a period of 42 years (1971-2012). The results of the study confirm the relationship between population growth and CO2 emissions, highlighting that pollution in developing countries will increase significantly over 50 years. The study offers theoretical and practical implications. It contributes to expand the scientific literature and debate on the environmental conditions of Africa and provides useful suggestions for policymakers to implement industrial, urban, and social policies to build a global sustainable development that includes the poorest countries.

**Keywords:** $CO_2$ emissions; ICT; developing economies; population growth; pollution; environment

**Doi: 10.5281/zenodo.12691411**

ISSN: 2724-0592 E-ISSN: 2724-1947
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## 1. Introduction

In recent years, the literature has paid much attention to the study of climate change. The greater attention by the scientific community to the topic of sustainability largely derives from the greater emphasis with which state governments, at all levels, are implementing climate risk mitigation policies. In 2021, the Intergovernmental Panel on Climate Change (IPCC) highlights how climate change is mainly due to human activity and how the implementation of policies aimed at mitigating it is therefore necessary (IPCC Report 2021). Climate change poses significant risks both for the health of people and from an economic point of view (Cevik & Jalles, 2021; WHO Report, 2009). However, it is also difficult to predict the trend of climate change (Kruttli et al., 2021).

Undeveloped countries could therefore suffer more from the costs of climate change because they are less capable, due to their geopolitical and economic situation, of dealing with it in a resilient way.

This study focuses on the analysis of the African continent, which is particularly exposed to rising temperatures, being particularly hot due to its geographical position, and being in a disadvantaged economic-political situation. The African continent is also the subject of numerous investments by foreign states and multinationals, which often tend not to improve the economic situation. Furthermore, Africa has a very high population growth rate, which also impacts environmental sustainability.

Despite the growing interest in emerging countries, in the literature the results relating to the variables examined are not entirely clear and are ambiguous. Positioning ourselves within this research gap, the analysis aims to identify the factors that cause environmental pollution, measured through $CO_2$ emissions, focusing on the relationship that exists between population growth and emissions, as well as on the role of the ICT sector.

To achieve this, a correlation analysis and linear regression is conducted, finding a statistically significant relationship between population growth and emissions. We formulate two research questions to which two hypotheses correspond:

*RQ1*: Is there a positive relationship between population growth and greenhouse gas emissions?

*H1*: There is a positive relationship between population growth and greenhouse gas emissions.

*RQ2*: What is the role of the growth of ICT in the greenhouse gas emissions?

*H2*: ICT growth has a statistically significant impact on greenhouse gas emissions.

The study provides significant theoretical implications, useful for those who in the future want to study environmental sustainability in Africa, and policy implications for those who will be called upon to implement climate change mitigation policies.

The study is therefore organized as follows: after the introduction, section 2 is dedicated to the critical review of the literature; section 3 explains the methodology; section 4 to highlight the results and, finally, section 5 to the conclusions, highlighting the limitations, implications, and future directions of the research.

## 2. Literature review

Scientific literature has increasingly focused on the relationship between environmental pollution and the growth of the ICT sector. The main reason is the growth of the attention on sustainability by governments, companies, and civil society (Asatani et al., 2020). The impact of ICT on environmental pollution is ambiguous it has the power to orient the ecological future of the world. The impact of ICT on environmental pollution is particularly negative on developing countries, while in developed countries it mitigates the environmental decline (Majeed, 2018). Another study by Magazzino et al. (2021), based on EU-countries, finds that ICT influences energy consumption and the latter has a negative effect on environmental sustainability. This means that there is an indirect negative influence of ICT on environmental pollution. Charfeddine and Umlai (2023) confirm the ambiguity of the relationship between the two considered variables, with 175 that identify a negative linear effect of ICT on environmental pollution. The same study distinguishes between first-, second- ant third- order effect. In our paper, following also Hilty et al. (2006), we consider the first-order effect, or the environmental degradation deriving by the energy consumption in ICT production and by the inadequate disposal of e-waste. Instead, several studies find a positive relationship between ICT and environmental sustainability. Khan et al. (2020) find that ICT reduced Co2 emissions and encourage to invest in ICT. Higón et al. (2017) find an inverted-U relationship between ICT and CO2 emissions, arguing that many developed countries achieve the level of ICT at which emissions decrease. This paper has a particular focus on Africa. This country is interesting for literature since it is receiving increasing attention from several countries, as China (Ajakaiye & Kaplinsky, 2009). The increasing of investment in Africa has an enormous impact on environmental sustainability (Asiedu, 2021). Many scholars pay attention to the drivers of environmental pollution and economic consequences in Africa. For example, Sekrafi (2021) finds studied the relationship between international tourism, growth, and environmental quality in North Africa, finding that that tourism has a direct and statistically significant impact on the level of emissions. In the African continent, the absence of climate change mitigation and adaptation interventions will lead to a loss of 4% of GDP, with a significant impact on agriculture, the main share of African GDP (Simbanegavi & Arndt, 2014). Africa is currently unable to exploit the benefits of renewables and an important political intervention is necessary, aimed at the development of the African continent (Schwerhoff & Sy, 2018). The African continent will suffer the effects of climate change in a disproportionate manner compared to its contribution to global emissions (Steiner, 2019).

Focusing again on ICT, the main pollution driver is the obsolescence of products used in Africa. The use of obsolete vehicles coming from Europe and East Asia is one of the leading factors responsible for increased air pollution in Africa (Ayetor et al., 2022). In addition, there are many countries where electricity supply is poor. Indeed, current data relating to African households indicates that approximately 600 million people do not have access to electricity (IEA, 2022). In Africa there are few large active companies. The main electricity connection lines are limited and above all concentrated in large urban centres. Furthermore, the cost of electricity is among the highest in the world (IEA, 2022). Another source of CO2 includes a cooking system that uses fire generated from classic charcoal, leaves, branches, and dried waste products (Sheahan & Barrett, 2017). This is practiced by approximately seven hundred million Africans (EPA, 2021). Unfortunately, in twenty-three countries on the continent, around 90% of people do not have a valid and functional alternative. The effects of these techniques are evident in the increase in CO2 emissions (Figure 1), which cause, among other, serious and irreparable damage to the respiratory and/or pulmonary system and to maternal embryos (EPA, 2021).

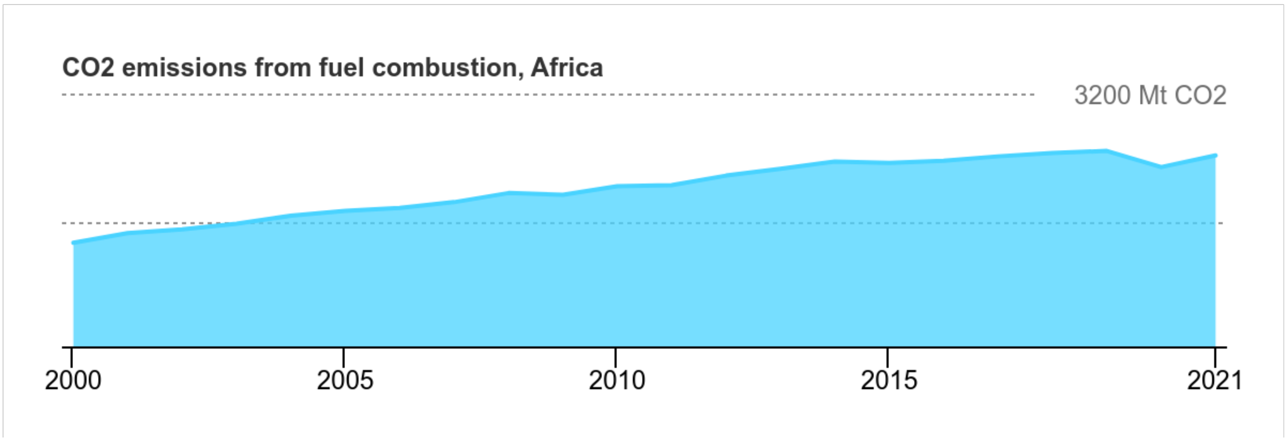


**Figure 1: Co2 emission. Source: IEA**

In addition, Africa is often the destination for e-waste. The speed with which products are consumed on the market, combined with the high costs of "regular" disposal, pushes multinationals to dispose of products no longer used in Africa (Forti et al., 2020). The African continent is also interesting because of its demographic trend. African population is constantly increasing, especially in sub-Saharan Africa, while EU countries, Japan and China will go through a period of demographic decline (Hara, 2022). According to Guengant & May (2013), the working age population of African countries will triple. It is necessary to aim to a demographic regime with low mortality and low fertility to reduce poverty and to achieve economic growth. Many scholars analyzed the relationship between demographic trend and environmental pollution, finding ambiguous results. Dimnwobi et al. (2021), studying five african countries, find a non-significant relationship between urbanization and environmental degradation. Another study by Haouas et al. (2023) find a positive effect of population density, total population, and urban population and CO2 emissions. Yang et al. (2022), conducting a scenario analysis, find that demographic factors have a relevant role in the future health burden from air pollution. Also, Cramer (2002) argues that there is a reciprocal causality between population growth and environmental pollution. It is necessary to develop a new paradigm balance the relationship between demography and sustainability Bersaglio (2016). In addition, Park, S.J. et al. (2011) analyzed the relationship between socio-demographic variables and environmental sustainability, finding a non-linear effect. Bhargava (2019) analyzed the need to achieve different approaches to manage climate change, especially regarding population health. The study finds that the management of population health and growth has a relevant role in achieving 2030 goals.

All these issues relating to the environmental impact of technology have significant consequences on both the health and economic development of the African continent and deserve greater attention from the literature. Based on the literature, we formulate the following research questions and hypothesis:

*RQ1:* Is there a positive relationship between and population growth and greenhouse gas emissions?

*H1:* There is a positive relationship between population growth and greenhouse gas emissions.

*RQ2:* What is the role of the growth of ICT in the greenhouse gas emissions?

*H2:* ICT growth has a statistically significant impact on greenhouse gas emissions.

## 3. Methodology

To address the purpose of the paper an analysis was conducted on Africa (Table 1[1]) over a 42-year period (1971-2012). The choice derives from the fact that South Africa is the main leader in CO2

[1] The international acronyms of each state are in brackets

emissions among African countries (IEA Ranking, Figure 2). The data on Co2 emissions were extrapolated from the World Bank and the World Resources Institute[2] and are therefore reliable.

| Sampled countries (2002–2012) | | | | |
|---|---|---|---|---|
| **North** | **Central** | **South** | **West** | **East** |
| Algeria (DZA) | Camerun (CMR) | Angola (AGO) | Benin (BEN) | Comore (COM) |
| Egypt (EGY) | Gabon (GAB) | Botswana (BWA) | Capo Verde (CPV) | Ethiopia (ETH) |
| Libya (LBY) | Sao Tomé and Principe (STP) | Lesotho (LSO) | Costa d'Avorio (CIV) | Kenya (KEN) |
| Tunisia (TUN) | Congo (COG/COD) | Mozambique (MOZ) | Gambia (GMB) | Mauritius (MUS) |
| Morocco (MAR) | | Namibia (NAM) | Ghana (GHA) | Seychelles (SYC) |
| | | South Africa (ZAF) | Guinea-Bissau (GNB) | Sudan (SDN) |
| | | Swaziland (SWZ) | Nigeria (NGA) | Tanzania (TZA) |
| | | Zambia (ZMB) | Senegal (SEN) | |
| | | Zimbabwe (ZWE) | Togo (TGO) | |

**Table 1: African countries divided by geographical areas.**

The variables considered are the following (Table 2):

| Variables | Definition | Characteristics of the used variables and references |
|---|---|---|
| TCO2 | Total Co2 emissions expressed in Kt | Dependent variable |
| POP | Number of the population of the state of South Africa | Independent variable |
| GDP | GDP-USD | Independent variable |

[2] For more informations: https://data.worldbank.org/; https://www.wri.org/data

| | | |
|---|---|---|
| EXP | Export level of goods and services calculated at the value of the US dollar US $ | Independent variable |
| EPC | Percentage share of total energy consumption from fossil carbon sources | Independent variable |
| EU | Used energy expressed in oil consumption (Kg) per capita | Independent variable |
| AT | Number of passengers who used air transport | Independent variable |
| IG | Import level of goods and services at the current value of the US dollar US $ | Independent variable |
| ICT | Percentage share of investment on imports of services, BoP, etc | Independent variable |

**Table 2: Variables. Source: Our elaboration**

| Rank | Country/Region | Mt CO2 | % |
|---|---|---|---|
| - | **Africa** | **2436.982** | |
| 1 | South Africa | 391.746 | 16.1 |
| 2 | Egypt | 206.831 | 8.5 |
| 3 | Algeria | 143.249 | 5.9 |
| 4 | Nigeria | 101.461 | 4.2 |
| 5 | Morocco | 67.411 | 2.8 |
| 6 | Libya | 41.191 | 1.7 |
| 7 | Tunisia | 26.892 | 1.1 |
| 8 | Ghana | 21.397 | 0.9 |
| 9 | Angola | 19.822 | 0.8 |
| 10 | Sudan | 19.513 | 0.8 |

**Figure 2: IEA emissions' raking. Source: IEA**

The study was conducted using a quantitative methodology with a correlation analysis and a panel data. Following other economics scholars we implemented the Spearman's index (Bakare, 2012; Shen et al., 2023).

The Spearman's correlation index (Figure 3) is a non-parametric index useful to measure the correlation between two variables. The index measures how well an arbitrary monotonic function can describe the relationship between two variables, but it does not make assumptions on the distribution of the variables (Hauke & Kossowski, 2011). Correlation analysis is useful in social studies, particularly if the study is conducted on a real-world dataset (Xiao et al., 2016). In the formula (Figure 3), d is the difference in the ranks of the two variables compared, and n is number of observations.

$$r_s = 1 - \frac{6\sum d_i^2}{N\left(N^2 - 1\right)}$$

**Figure 3: Spearman's correlation index. Source: Xiao et al., 2016**

Panel data analysis[3] has several advantages and is it is widely used in economics literature (e.g. Aşıcı, 2013). The model used in study is the following:

$$TCO2 = \beta_1 POP + \beta_2 ICT + \boldsymbol{\beta} W + \varepsilon_{it}$$

In the model, the dependent variable is the total of the emission for each country. The interest variables are population and ICT, while $W$ is the vector of control variables and should not be interpreted in a causal way. In the end, $\varepsilon_{it}$ is the stochastic error. We implemented a fixed effect

[3] For more details see: Stock & Watson https://www.sea-stat.com/wp-content/uploads/2020/08/James-H.-Stock-Mark-W.-Watson-Introduction-to-Econometrics-Global-Edition-Pearson-Education-Limited-2020.pdf

model. The used variables are consistent with literature (Kojo & Paschal, 2018; Byrne & Corrado, 2017; Chakraborty & Mukherjee, 2013).

The analysis was implemented using Graph Pad Prism 5.0, of the most popular software in econometric and statistical analysis, following other scholars (e.g. Liao et al., 2018).

## 4. Results

For each variable, we first calculated the main descriptive statistics (Tabel 3):

| | TCO2 | POP | GDP | EXP | EPC | EU | AT | IG | ICT |
|---|---|---|---|---|---|---|---|---|---|
| Min. | 168568 | 23482813 | 2,03E+13 | 4,33E+12 | 2162 | 1913 | 1659500 | 4,74E+12 | 0,67708333 |
| 1st Qu. | 263214 | 30732280 | 8,23E+13 | 2,12E+13 | 3553 | 2273 | 3986650 | 1,75E+13 | 19.10 |
| Median: | 335012 | 38899040 | 1,23E+14 | 3,08E+13 | 4089 | 2463 | 5473200 | 2,61E+13 | 0,94027778 |
| Mean | 331118 | 38694483 | 1,43E+14 | 3,96E+13 | 3890 | 2421 | 6804378 | 3,73E+13 | 22.28 |
| 3rd Qu. | 384265 | 46865881 | 1,55E+14 | 3,70E+13 | 4492 | 2619 | 8039684 | 3,45E+13 | 24.20.00 |
| Max. | 503112 | 52998213 | 4,17E+14 | 1,27E+14 | 4777 | 2913 | 17571565 | 1,24E+14 | 31.63 |

**Table 3: Descriptive statistics. Source: our elaboration**

The correlation analysis was performed putting on y axis the years and on x axis the CO2 levels emissions. Co2 emissions that are also correlated with people health (Table 4).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Number of XY Pairs | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| r | 0,9642 | 0,8911 | 0,8616 | 0,9189 | 0,8986 | 0,8942 | 0,8414 | 0,1395 |
| 95% confidence interval | 0.9340 to 0.9807 | 0.8052 to 0.9404 | 0.7555 to 0.9237 | 0.8533 to 0.9559 | 0.8181 to 0.9446 | 0.8105 to 0.9421 | 0.7220 to 0.9121 | -0.1717 to 0.4255 |
| P value (two-tailed) | P<0.0001 | P<0.0001 | P<0.0001 | P<0.0001 | P<0.0001 | P<0.0001 | P<0.0001 | 0,3781 |
| P value summary | *** | *** | *** | *** | *** | *** | *** | ns |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Is the correlation significant? (alpha=0.05) | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |
| R squared | 0,9297 | 0,7940 | 0,7424 | 0,8444 | 0,8075 | 0,7995 | 0,7079 | 0,01947 |

**Table 4: Correlation analysis**

The regression analysis (Figure 4) shows a statistically significant relationship between population growth and emissions, therefore supporting hypothesis *H1*, while, based on the data collected, hypothesis *H2* is not supported, as ICT is not statistically significant. Our results are consistent with previous literature that found a significant relationship between demographic factors and Co2 emissions (Haouas et al. 2023). This means that is necessary to implement demographic policies to build a sustainable development. The continuous population growth is no longer sustainable. The result, at the end, address the necessity of Africa to have a modern demographic regime Guengant & May (2013). In other way is necessary to reduce the fertility rate and the mortality rate. Regarding ICT, the coefficient is not statistically significant, consistent with some literature Charfeddine and Umlai (2023). This means that the relationship between ICT and pollution is not clear and depends by countries and proxy used. To measure ICT, as show in the precedent paragraph, we use the percentage share of investment on imports of services, so is possible that using other proxy, the significance could change. The analysis is not able to explain a clear first-order effect between Co2 emissions and ICT growth, but future research could try to better explain this relationship using other data or methods. We use other variables as control, so the significance should not be interpreted as statical correlation or causality. From an economic point of view, is convenient for African countries the emissions reductio. Some scholars provide evidence that support the hypothesis on the relationship between environmental sustainability and economic growth in emerging countries (Ma et al. 2023).

The study suggest that is need for Africa to reduce its emissions to achieve better life quality for its people and sustainable economic growth. Other countries could help Africa in its green transition, implementing an inclusive green growth (Ofori et al., 2023).

| | POP | GDP | EXP | EPC | EU | AT | IG | ICT |
|---|---|---|---|---|---|---|---|---|
| *Best-fit values* | | | | | | | | |
| *Slope* | 89.69 ± 3.900 | 930500 ± 74930 | 275300 ± 25640 | 0.006942 ± 0.0004712 | 0.002306 ± 0.0001780 | 37.70 ± 2.985 | 280800 ± 28520 | 0.000006446 ± 0.000007232 |
| *Y-intercept when X=0.0* | 8995000 ± 1346000 | -164700000000 ± 25860000000 | -51580000000 ± 8849000000 | 1591 ± 162.6 | 1657 ± 61.43 | -5680000 ± 1030000 | -55710000000 ± 9842000000 | 20.14 ± 2.496 |
| *X-intercept when Y=0.0* | -100300 | 177000 | 187300 | -229200 | -718800 | 150600 | 198400 | -3125000 |
| *1/slope* | 0,01115 | 0,000001075 | 0,000003632 | 144,0 | 433,7 | 0,02652 | 0,000003562 | 155100 |
| *95% Confidence Intervals* | | | | | | | | |
| *Slope* | 81.81 to 97.58 | 779100 to 1082000 | 223500 to 327100 | 0.005990 to 0.007895 | 0.001946 to 0.002666 | 31.67 to 43.74 | 223100 to 338400 | -0.000008170 to 0.00002106 |
| *Y-intercept when X=0.0* | 6275000 to 11720000 | -217000000000 to -112400000000 | -69460000000 to -33690000000 | 1263 to 1920 | 1533 to 1782 | -7762000 to -3598000 | -75600000000 to -35820000000 | 15.10 to 25.19 |
| *X-intercept when Y=0.0* | -142800 to -64490 | 142500 to 203200 | 148400 to 215700 | -319400 to -160500 | -913600 to -576400 | 112300 to 179500 | 157600 to 227600 | -infinity to -723400 |
| *Goodness of Fit* | | | | | | | | |
| *r²* | 0,9297 | 0,7940 | 0,7424 | 0,8444 | 0,8075 | 0,7995 | 0,7079 | 0,01947 |
| *Sy.x* | 2460000 | 47260000000 | 16170000000 | 297,2 | 112,3 | 1883000 | 17990000000 | 4,561 |
| *Is slope significantly non-zero?* | | | | | | | | |
| *F* | 528,9 | 154,2 | 115,3 | 217,1 | 167,8 | 159,5 | 96,93 | 0,7944 |
| *DFn, DFd* | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 | 1.000, 40.00 |
| *P value* | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | 0,3781 |
| *Deviation from zero?* | Significant | Significant | Significant | Significant | Significant | Significant | Significant | Not Significant |
| *Data* | | | | | | | | |
| *Number of X values* | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| *Maximum number of Y replicates* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Total number of values* | 42 | 42 | 42 | 42 | 42 | 42 | 42 | 42 |
| *Number of missing values* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 4: Regression analysis**

## 5. Conclusion

Our study conducted a correlation and regression analysis on the African continent between 1971 and 2012 to study the relationship between population growth (H1) and environmental pollution (greenhouse gas emissions), looking for to also understand the role of the growth of the technological sector on emissions (H2).

The results show that population growth has a positive and statistically significant impact, while the ICT variable is not significant, therefore the hypothesis H1 is verified, consistently with the previous literature, while the study is not able to clarify the ambiguity present in the literature on the relationship between ICT and emissions in Africa.

The analysis conducted, however, poses some important theoretical and policy implications. First, it contributes to expanding the literature on the African continent, which is still not sufficiently developed and, specifically, the line of research that deals with the study of climatic conditions and sustainable development on the African continent. Regarding the policy implications, the study suggests to policy makers the implementation of policies aimed at building sustainable development that concerns all continents, including the African one, which is not capable, at present and due to the geopolitical situation, self-sufficient in the implementation of effective environmental policies. Policies aimed at managing fertility and mortality rates are necessary, as well as incentivizing the mitigation of climate change, given that Africa is already a hot country, because of its geographical position. Given the unclear direction of technology's effect on the environment, it could also represent a positive factor in mitigating climate change. Specifically, technological progress should lead indirectly to the creation of Smart Cities, innovative factories, and agriculture with modern cultivation techniques that allow the elimination of pesticides by developing eco-sustainable solutions (Secinaro et al., 2022). In addition, to reduce pollution from scheduled obsolescence products, measures should be implemented to extend the legal guarantee of an asset from the current 2 to 5 years for all products and to 10 for cases where it is reasonable to assume a particularly long duration. To oblige manufacturers to ensure the availability of spare parts for as long as the asset is put into circulation in the market and in any case with a cost always proportional to the selling price of the asset. Implement dissuasive measures such as penalties and fines to dissuade companies from resorting to illegal and improper disposal practices.

Focusing on the theoretical implications, the study, while expanding the literature, has some limitations, which can be a starting point for future research. First, the study does not clarify the relationship between ICT and pollution and uses little granular data. Future studies could focus on considering other proxies for studying ICT or climate change. Future research could then consider possible moderating effects of technology, consider other econometric techniques or qualitative studies. Finally, it could be useful to carry out cross-country studies to identify and study in a comparative way the factors that influence pollution.

**Acknowledgment:** The authors thank the Editor, the Editorial Board and the anonymous reviewers for the support provided and the precious suggestions given in the publication of the paper.

**Conflict(s) of interests:** The authors declare that they have no conflicts of interest.

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