The ecological footprint in Africa: Identifying convergence clubs from 1970 to 2018[1]

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ABSTRACT

Understanding the dynamics of air emissions is important in implementing efficient policies to combat climate change, and the convergence of air pollutants is a major concern for planners. Nevertheless, most of the existing evidence focuses on developed regions. In this paper, we analyze the evolution of the ecological footprint for the African continent, during 1970-2018. The Phillips and Sul (2007, 2009) panel club convergence approach is carried out. This framework allows us to test the null hypothesis of absolute convergence for a pool of data and to identify groups of countries that converge to the same steady state. Our results offer important insights into the emissions catch-up exhibited by these countries, but do not support the hypothesis that all countries of the African region converge to a single equilibrium. The empirical results strongly support the existence of two convergence clubs. Our empirical findings have important implications for African policymakers in terms of mitigation policies, as the results suggest that a common environmental policy across the entire African continent is sub-optimal, since these regions have heterogeneous behaviors and move towards different equilibriums. Hence, the policies against global warming must be designed among countries that share a common trajectory.

KEYWORDS: convergence analysis; Africa; ecological footprint; club convergence test

JEL CLASSIFICATION: C33; O55; Q01; Q53

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1. Introduction

The dynamics and convergence of pollutant emissions are critical issues for forecasting the future of environmental pollution and planning appropiate climate policies, in both developed and developing economies. Indeed, most of the long-run climate change models and international commitments are based on pollutant convergence assumptions. At this point, determining convergence of countries in terms of environmental indicators may help planners to design more effective environmental policies to combat global warming. However, most studies focus only on the developed countries and this empirical body of literature is scarce in developing regions such as Africa, which could lead to quite likely sub-optimal policies in case of divergence.

In this paper, we try to contribute to the existing literature by studying the dynamics of the ecological footprint in Africa. Specifically, we assess whether there has been a convergence process of ecological footprint among 35 African countries, during 1970-2018. The environmental convergence process among African countries has been explored in very few empirical studies, using different econometric techniques, samples and periods. Solarin (2014) investigates per capita CO_2 emissions in 39 African countries during 1960-2010, and his results reveal that 80% of the sample are stochastically convergent. Later, Tiwari et al. (2016) also find evidence for stationarity in per capita CO_2 emissions for 35 African countries. Thus, most of the existing literature on environmental convergence in Africa focuses on CO_2 emissions, but several authors (Bilgili and Ulucak 2018; Ulucak and Apergis 2018; Solarin et al. 2019; Erdogan and Okumus 2021; Işik et al. 2021; Tillaguango et al. 2021; Alvarado et al. 2022) have pointed out that ecological footprints allow taking into account the environmental pressures of human activities in all dimensions required to produce the sources consumed by the community, and provide a basis for setting environmental goals. However, only Ulucak et al. (2020) has employed this measure in Africa, studying club convergence of ecological footprints in 23 countries of Sub-Saharan Africa, during 1961-2014.

Hence, the results from this study contribute to a more in-depth understanding of the evolution of the ecological footprint in Africa, which allows for the implementation of more efficient environmental policies. This study seeks to bridge the existing research gap by examining the club convergence of the ecological footprint across the entire Africa continent over the last five decades, and by identifying the countries that form each club. Furthermore, we estimate the speed of convergence of the different clubs. The important questions to be tested are: i) do ecological footprints converge to a unique equilibrium?, ii) if not, are there distinct convergence clubs?, and iii) are the common environmental policies adequate?

To do this, we use the convergence technique developed by Phillips and Sul (2007, 2009). This convergence approach has clear advantages over alternative methods: first, it identifies endogenously groups of countries converging towards the same equilibrium in a panel, along with any divergent regions, although the null hypothesis of absolute convergence is rejected. Second, the speed of convergence can be estimated. Finally, the methodology does not suffer from small-sample and does not depend on the stationarity properties.

The remainder of the paper is structured as follows. Section 2 describes the data. Section 3 discusses our findings, and Section 4 presents concluding remarks and policy implications.

2. Data

Table A1 in the Appendix details the data used for the analysis. South Africa, and Botswana are the largest contributors to the ecological footprint in Africa (with an average of 3.572, and 2.820 global hectares per person), whereas Democratic Republic of the Congo has the lowest ecological footprint (mean value equal to 0.023). Although the African continent has reduced its total ecological footprint at a cumulative annual rate of 0.273%, countries have not experienced the same growth rates. This could lead to inappropriate environmental policies.

The concept of convergence refers to a decrease of the dispersion among countries, and Figure 1 shows the cross-sectional coefficient of variation (CV) of the ecological footprint. When the CV decreases over time, it can be interpreted as evidence of sigma-convergence. Nevertheless, the CV of ecological footprint does not exhibit a decreasing trend.

[Figure 1 here]

3. Results

Here we discuss the main results of the club convergence analysis, reported in Table 1. We first test the full panel convergence (results in Panel A of Table 1). When the total sample is considered, the *t*-statistic for the log *t* test is –12.717, lower than the critical value at the 5 percent level of significance (-1.65). This implies rejection of the null hypothesis of overall ecological footprint convergence and suggests that these countries have not converged to the same steady state.

Phillips and Sul (2007) argue that rejection of the null hypothesis of full convergence does not mean that there are no convergence clubs, and we apply the cluster algorithm to consider the possible existence of convergence clubs for those countries that have the same pace of convergence. The results for the club-clustering algorithm are presented in Panel B of Table 1, and illustrate the presence of two distinct clubs. Club 1 is the largest and contains 27 countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Democratic Republic of Congo, Gambia, Ghana, Guinea, Guinea-Bissau, Lesotho, Malawi, Mali, Mozambique, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Togo, Zambia, and Zimbabwe, with the coefficient b on log t equal to 0.010 and t-stat equal to 0.050 (a positive t-statistic above the critical value of -1.65), failing to reject the null hypothesis of convergence. Club 2 has eight countries: Burundi, Ethiopia, Kenya, Madagascar, Rwanda, Somalia, Tanzania, and Uganda, with b=1.415 and t-stat=1.157 (greater than the critical value). Thus, we do not reject the null hypothesis of club convergence and the evolution of the ecological footprint in Africa shows important differences across countries according to the endogenous groups detected. More specifically, our results imply that African countries are clustered into two clubs. Although the club converging algorithm tends to overidentify the actual number of clubs (Phillips and Sul 2009), the club-merging analysis in Panel C also reveals two distinct clubs.

Our main conclusion is that we reject the null hypothesis of convergence for the ecological footprint, and the existence of convergence clubs is comparable with prior work, such as Bilgili and Ulucak (2018), Ulucak and Apergis (2018), Haider and Akram (2019), Solarin et al. (2019), Ulucak et al. (2020), Apaydin et al. (2021), Erdogan and Okumus (2021), and Tillaguango et al. (2021). All these works study ecological footprint convergence and use the same methodology, in different geographical contexts, providing evidence for the existence of convergence clubs.

[Table 1 here]

Figure 2 displays the evolution of the average ecological footprint per capita of the estimated clubs. Both clubs 1 and 2 show a decrease in the ecological footprint per capita, but at different speeds, since Club 2 decreases at a faster rate. This result is also justified by the speed of convergence; we observe that the speed of convergence for Club 2 is around

0.7075 (the estimated b parameter is 1.415), whereas countries in Club 1 converge at a rate of 0.005 (b coefficient equal to 0.01). The greater distance among clubs at the end of the period illustrates the absence of overall convergence.

[Figure 2 here]

4. Conclusion and policy recommendations

This paper analyses the convergence process of the ecological footprint across African countries, identifying groups of countries that converge to the same steady state. It seems appropriate to analyze the convergence hypothesis in more homogeneous regions and here we contribute to the environmental convergence literature by considering a large sample of African countries. We focus on the environmental degradation produced by human activity and analyze the evolution of the ecological footprint from 1970 to 2018. Convergence in air pollutants has attracted considerable attention but there remains much to be studied in Africa.

First, we examine the sigma-convergence approach and calculate the CV. The result suggests that the differences among African countries in the ecological footprint tend to increase over time, which does not support sigma-convergence. Next, we use the Phillips and Sul methodology, a technique that allows us to contrast the null hypothesis of convergence and endogenously determine groups of countries that converge to a single equilibrium. Our results show clear evidence against the null hypothesis of overall convergence, implying that the ecological footprint is not uniform across countries, and suggesting the presence of two convergence clubs that tend to different steady states. Interestingly, we do not find any divergent group of countries in the pooled data.

Thus, a common environmental policy across the entire African continent to reduce the ecological footprint seems to be sub-optimal, and egalitarian rules have a low degree of efficacy across the continent, since these countries have different patterns of behavior. Policies should take into specific consideration the unique path of each club, and mitigation policies need to be conducted across convergent countries for better environmental outcomes. Our results reveal a need for modifying policies according to the existence of club convergence and we propose that African agreements should be reviewed, and sanctions could be established to ensure efficient implementation of mitigation policies. Furthermore, policymakers should promote eco-friendly technologies, and move to renewable energy sources to extend the use of clean energy alternatives. At this point, a carbon tax to minimize the ecological footprint is also encouraged.

The main limitation of this study is that the technique only allows us to address convergence using a single indicator. Thus, a valuable future research direction would be to extend the convergence of the ecological footprint to its six sub-components (built-up land, cropland, fishing grounds, forest land, grazing land, and carbon footprint). Besides, it is not possible to identify which factors lead to the multiplicity of equilibriums and determine what are the main drivers that affect the formation of convergent clubs is also a future avenue. Several authors have pointed out that cross-country aggregate data tends to mask subnational differences (Ivanovski and Churchill 2020). Thus, it would also be worthwhile for policymakers to investigate convergence at the sectoral or subnational level. Finally, future research could explore how the COVID-19 affected the behavior of the ecological footprint, as data becomes available.

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Figure 1. Coefficient of variation

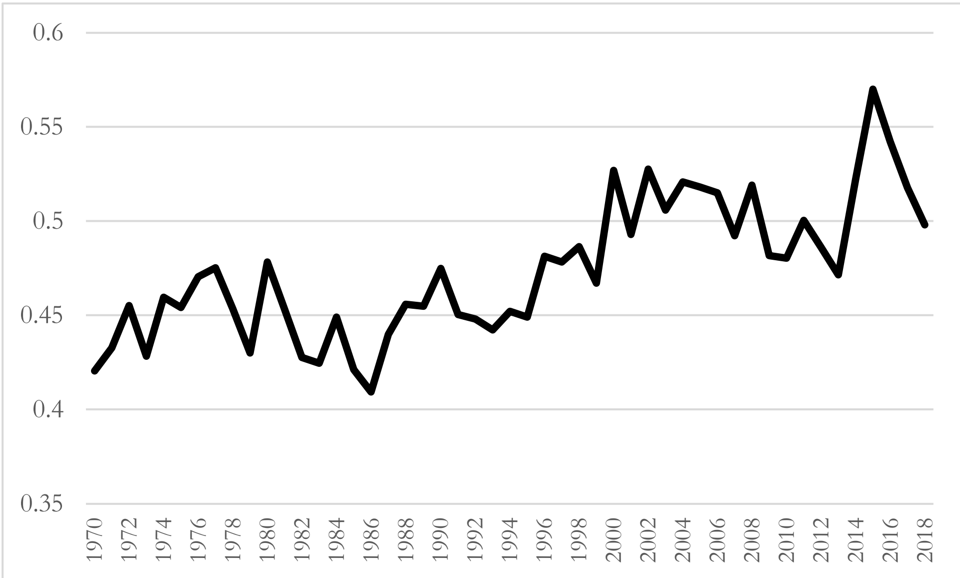

Table 1. Convergence analysis

Panel A. Overall convergence test		
$\hat{b}$ coefficient		*t*-stat
-1.644		-12.717*
Panel B. Convergence club tests		
Club 1 [27]		
AGO, BEN, BFA, BWA, CAF, CMR, COD, COG, CIV, DZA, GHA, GIN, GMB, GNB, LSO, TCD, MLI, MOZ, MWI, NER, NGA, SEN, SLE, TGO, ZAF, ZMB, ZWE		
$\hat{b}$ coefficient		*t*-stat
0.010		0.050
Club 2 [8]		
BDI, ETH, KEN, MDG, RWA, SOM, TZA, UGA		
$\hat{b}$ coefficient		*t*-stat
1.415		1.157
Panel C. Club merging test		
	$\hat{b}$ coefficient	*t*-stat
Merging Clubs 1 + 2	-1.644	-12.717*

Notes: * indicates rejection of the null hypothesis of convergence at the 5% level. The term *b* coefficient stands for a parameter that is twice the rate of convergence of each club. Entries in square brackets represent the number of countries in a group.

Figure 2. Average values of the clubs

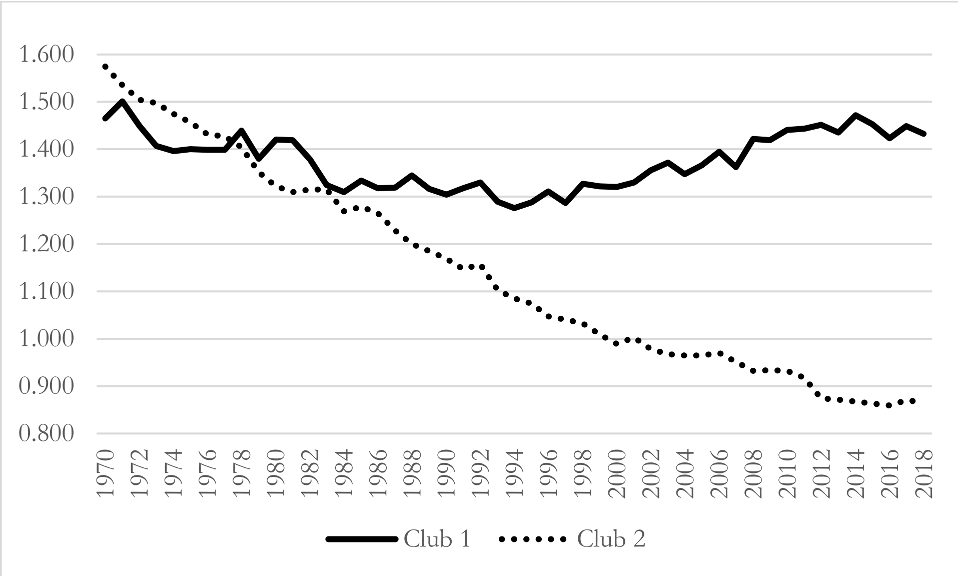

Table A1. Sample details

Variable	Measure	Sample	Period	Source
Ecological footprint	Global hectares per person	Algeria (DZA), Angola (AGO), Benin (BEN), Botswana (BWA), Burkina Faso (BFA), Burundi (BDI), Cameroon (CMR), Central African Republic (CAF), Chad (TCD), Congo (COG), Côte d'Ivore (CIV), Democratic Republic of the Congo (COD), Ethiopia (ETH), Gambia (GMB), Ghana (GHA), Guinea (GIN), Guinea-Bissau (GNB), Kenya (KEN), Lesotho (LSO), Madagascar (MDG), Malawi (MWI), Mali (MLI), Mozambique (MOZ), Niger (NER), Nigeria (NGA), Rwanda (RWA), Senegal (SEN), Sierra Leone (SLE), Somalia (SOM), South Africa (ZAF), Tanzania (TZA), Togo (TGO), Uganda (UGA), Zambia (ZMB), and Zimbabwe (ZWE)	1970-2018	Global Footprint Network