MEASURING SUSTAINABLE DEVELOPMENT IN THE CARIBBEAN: A STOCHASTIC DOMINANCE APPROACH USING ECOLOGICAL FOOTPRINT DATA

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ABSTRACT

Using a newly assembled cross-country data set on ecological footprints we compare the extent of environmental quality in the Caribbean over time and relative to other developing countries. Our methodological approach entails the use of stochastic dominance tests that allow comparisons across the whole distribution of environmental quality and are explicitly based on a utility maximizing framework. Statistical significance of these tests is based on bootstrapping procedures. We also conduct our tests conditional on differences in the stages of economic development.

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1.0 Introduction

Since the Brundtland Report (1987) the concept of sustainable development, defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p.43), has been of considerable interest in the economics literature. In this regard one should note that sustainable development is fundamentally a dynamic concept and thus intimately linked to the literature on economic growth. More specifically, the process of development and growth inherently requires some degree of depletion of partly non-renewable resources. Once the rate at which resources are used exceeds the rate at which they can be regenerated, however, the study of economic growth cannot ignore questions of sustainability, at least if one is interested in long term economic development.

In the present study, we focus our attention on the evolution of sustainability of development in the Caribbean by examining whether the extent of environmental quality in the region has improved or deteriorated across time and how it stands relative to other developing regions. To undertake this we address two main challenges inherent in such an analysis: (i) the selection of an appropriate indicator that takes account of nature's self-regeneration capacity; (ii) accounting for the entire distribution of our measure of environmental quality, rather than comparing means. To achieve these goals we employ stochastic dominance tests on recently assembled cross-country/time ecological footprint data.

Comparing measures of environmental quality across regions and/or time periods ideally calls out for some desirable underlying properties of the analysis. In particular, the goal entails comparing the relative desirability of situations and thus implicitly has some sort of social welfare preference ordering in mind. In this regard, simply comparing means of some measure of environmental quality, as has been traditionally done, would be implicitly assuming a very unrealistic social welfare function and contrary to rudimentary utility analysis. Recently a number of studies have attempted to address this problem by introducing stochastic dominance tools to assess environmental quality. For example, Millimet and List (2003) analyze whether a number of environmental legislative pieces introduced in the 1980s in the US have had adverse effects on environmental quality as measured by pollutants. In order to do so, they use stochastic dominance tests to compare state-level measures of pollution across time. Maasoumi and Millimet (2005) extend this stochastic dominance framework by allowing for the conditioning of differences in pollution on income levels, as these two variables are supposed to be closely interrelated. This extension implicitly allows one to take account of the fact that economic development will inherently entail a greater strain on natural resources and pollution generation, so that strictly comparing environmental quality across regions could arguably be 'unfair' to those regions at a lower portion of the development path. In the present study, we adopt analogous methods similar to those in the aforementioned papers for our study of sustainable economic development in Caribbean economies.

There is now a large body of literature in economics, referred to as the Environmental Kuznets Curve, that has tried to link environmental pollution and economic development, providing thereby a first insight into the concept of sustainable development.[1] Apart from being essentially empirical (notable exceptions are John and Pecchenino (1994) and John et al. (1995), Selden and Song (1995), Jones and Manuelli (2001), Brock and Taylor (2004) and Bertinelli et al. (2005)), one notable weakness of the literature in this regard has arguably been the inability to provide a realistic benchmark for what might be considered a sustainable development path. More precisely, by only examining the 'pollution' aspect of environmental quality one is ignoring nature's regeneration capability. It is thus pertinent to also take into account the trade-off between the depletion of resources and the ability to regenerate these

[1] See, for instance, Bertinelli and Strobl (2005).

when measuring sustainability. In other words, countries (regions) should be assessed not only in terms of the extent of pollution of their environment but also with regard to their contribution in terms of rebuilding natural capital. In the present study, we will rely on so-called footprint data, which measures "how much land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology".[2] When confronting per capita footprint with per capita biocapacity (i.e. the regeneration capacity of nature) we thus end up with a much more realistic indicator of (un)sustainability of the development path.

The rest of the paper is organized as follows. In the next section, we present our data and some summary statistics. Section II contains an outline of the stochastic dominance methodology. In Section III we provide the results of employing this methodology to our data. We conclude in the final section.

2.0 Data Description

2.1 Footprint and Biocapacity Data

Our study relies on ecological footprint data provided by the Global Footprint Network to measure environmental quality.[3] The ecological footprint is an aggregate measure of consumption, expressed in equivalent land area that is needed for food, resources, energy, and carbon dioxide emissions as a result of human activity. Thus ecological footprint accounts for the necessary productive space required to sustain a country's total consumption and the assimilation of its waste, given the prevailing technology in use. Ecological footprint therefore does not account for potential technological advances in the future when

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[2] Definition taken from the Global Footprint Network: http://www.footprintnetwork.org.

[3] Description of the data is essentially based on Wackernagel et al. (2005) and Monfreda et al. (2004).

generating footprint data in terms of equivalent land area. However, since this static account presents a yearly picture of ecological demand and supply, it captures annual changes in available technologies and management.

The Ecological Footprint data is derived from FAOSTAT's Food Balance Sheets, which is a database on production, import, and export using a unified framework. Further sources used to obtain measures of Ecological Footprint can be retrieved from Wackernagel et al. (2005). In order to end up with a usable measure of humanity's demand on nature, the ecological footprint measures the demand of bioproductive areas. Accordingly, using conversion factors, each area is weighted in proportion to its potential annual production of usable biomass. These conversion factors are obtained by taking the ratio of average national productivity to global productivity of different areas, such as cropland, rangeland, forests, oceans etc. (see Wackernagel et al. (2005) for further details). According to this method, globally there are 11.2 billion hectares of usable bioproductive areas. In order to obtain figures of Ecological Footprint, i.e. the demand on nature expressed in terms of *global hectares*,[4] it is supposed that one global hectare is equal to one hectare with productivity equal to the average productivity of the 11.2 billion bioproductive hectares worldwide. Thus, one hectare of highly productive land is equal to more global hectares than one hectare of less productive land. Global hectares are normalized so that the number of actual hectares of bioproductive land and sea on this planet is equal to the number of global hectares on this planet. Globally, the number of unadjusted hectares and the number of global hectares of bioproductive space are identical. It is

[4] A global hectare is defined as one hectare of biologically productive space with world-average productivity.

important to note that Ecological Footprint data consider consumption, which is calculated by adding imports to, and subtracting exports from, domestic production[5], rather than production in order to measure the sustainability of a country's development. Usually, in national accounts, products produced within a country are distinguished from products consumed by a country.

While Ecological Footprint documents the demand side of natural resources, the supply side, which is referred to as a nation's *biocapacity*, is measured as the sum of bioproductive areas, also expressed in global hectares. In order to transform bioproductive areas into global hectares, each area unit is appropriately multiplied by a conversion factor, similar to the ecological footprint.

In the present study, we are going to focus our attention on net footprint, i.e. footprint after subtracting biocapacity. Thus, positive net footprint values will imply that countries will have to consume part of their stock of resources to overcome their excessive consumption.

2.2 Income Per Capita Data

In part of our statistical analysis we will use income per capita in order to condition on levels of economic development when comparing our proxies of environmental quality. Income per capita is measured in terms of GDP per capita in thousands of dollars, where the data stems from Maddison (2001, 2003) and are appropriately adjusted for purchasing power parity (and expressed in 1990 International Geary-Khamis dollars). One should note that income per capita has a number of drawbacks in this regard, two of which are of direct interest in the present study: (i) income (or GDP) per capita does not take into account factors

[5] Despite these adjustments for trade, some consumption activities, such as tourism, are attributed to the country where they occur, or where planes are fueled, rather than to the travelers' countries of origin. This distorts the relative size of some countries' footprints, but does not affect the global result.

affecting the quality of life, such as the environment; (ii) income per capita is a measure of mean rather than median wealth, and thus makes no distinction between a skewed or a uniform distribution of per capita income across the population, i.e. income inequality is not taken into account. We ignore these these two aspects when conditioning on income in the present study since our focus is rather to measure sustainable development. Attempting to incorporate income inequality and quality of life into our study would make the analysis inherently more complex.

2.3 Descriptive Statistics

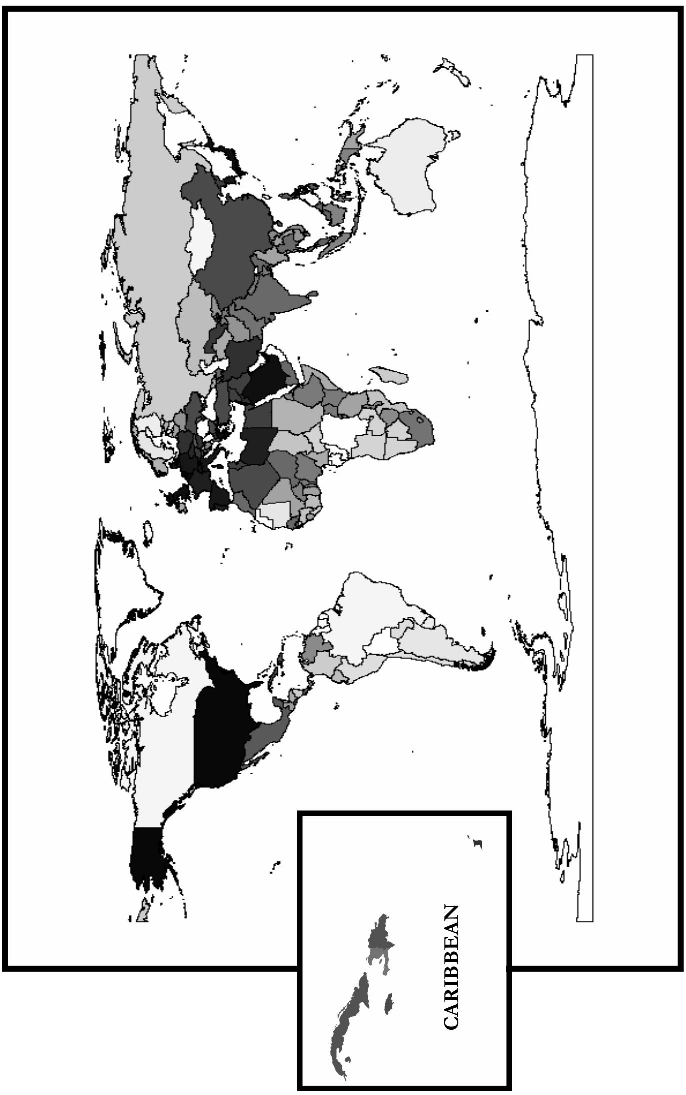
The two main variables of interest, net footprint and income per capita are available over the period 1961 to 2000. Table 1 displays mean values for each of these variables, for the years 1961, 1980 and 2000, for the Caribbean, other regional groupings, as well as the total of developing countries with and without the Caribbean. A first important observation concerns the evolution of net footprint over the 40 years of observations. More specifically, net footprint, measured as human demand on nature from which biocapacity, i.e. available supply of natural resources, is subtracted, has decreased continuously over the period. The fact that on average overall developing countries, net footprint is still negative means that on average the developing world's consumption still does not exceed its capacity to regenerate natural resources. The same is not true worldwide, as in the late 1980s, overall consumption of natural resources had exceeded the earth's biocapacity. However, examining the country group breakdown, one discovers considerable heterogeneity in this regard, as the Caribbean, South Asia and the Middle East and North Africa have already reached consumption levels exceeding natural regeneration capacities. Moreover, the Caribbean countries were the first group of developing countries in our sample which reached positive values of net footprint as early as the 1960s.

In terms of GDP per capita, the close geographical proximity between Latin American countries and the Caribbeans is reflected in the similarity of the levels and evolution of GDP per capita values. Furthermore, unsurprisingly, sub-Saharan African countries have had and still have the lowest level, whereas Asian countries have been facing the highest growth rates over the 40-year period.

Table 1: Descriptive statistics

	Net footprint			GDP per capita		
	1961	*1980*	*2000*	*1961*	*1980*	*2000*
Caribbean	0.24	1.04	0.73	2669.23	4364.33	4806.72
Sub-Saharan Africa	-5.87	-3.29	-1.50	1119.50	1415.32	1497.20
East Asia	-3.56	-1.94	-0.63	974.62	1792.23	2952.59
South Asia	-0.05	0.09	0.18	812.24	971.40	1644.83
Latin America	-7.05	-3.84	-2.12	3056.64	4662.04	5023.63
Middle East and North Africa	-0.43	0.92	1.34	2178.71	4843.75	3894.38
LDCs	-4.42	-2.17	-0.91	1824.71	2897.25	3093.58
LDCs (except Caribbean)	-4.67	-2.34	-0.99	1777.26	2816.64	2999.45

Finally, in Map 1, we have depicted net footprint values on a world map, with higher values of net footprint depicted in darker colour. Unsurprisingly, the developed countries unambiguously display the highest contribution to the consumption of natural resources, whereas the lowest values are found in Africa. Values for the Caribbean, depicted in the box, are relatively similar across its member nations.



Map 1: Net Footprint

3.0 Stochastic Dominance

Following Maasoumi and Millimet (2005), inherent in our analysis is the assumption that societies care about pollution and that pollution is considered a 'bad'. We will also assume that an unequal distribution of pollution across countries is undesirable. One may think of this as a preference of fairness, where it is, *ceteris paribus*, preferable that countries have similar contributions to environmental quality, rather than having some greater and some lesser contributors. Furthermore, pollution is often associated with threshold effects, above which pollutants are harmful. Thus using a simple summary measure, such as means, may be considered too restrictive.

We denote W_1 the class of (decreasing) social welfare functions, w where these are decreasing in pollution ($w' \leq 0$) and W_2 a sub-class of these where $w'' \leq 0$. One should note that the concavity in the welfare function ensures aversion to unequal levels of pollution across countries. In seeking to compare pollution across countries at any point in time, or across time for any set of countries, we assume that $\{x_i\}_{i=1}^{N}$ is a vector of N strictly stationary, α-mixing, possibly dependent observations of a pollution variable X and $\{y_i\}_{i=1}^{N}$ the analogous vector of a pollution variable Y, and let $F(x)$ and $G(y)$ be continuous and differentiable cumulative density functions (CDF) of X and Y, respectively. The distribution of X dominates Y in the first order sense, i.e. X *FSD (first order stochastically dominates)* Y, for the union of supports of X and Y, ***Z***, *if*:

$$F(x) \geq G(x) \qquad \forall x \in \boldsymbol{Z}, \text{ with strict inequality for some } x. \tag{1}$$

This may be alternatively expressed as:

$$q_x(p) \leq q_y(p) \qquad \forall p \in [0,1]Z \text{, with strict inequality for some } p, \tag{2}$$

where $q_x(p)$ and $q_y(p)$ are the p^{th} quantile of each distribution such that $\inf.\Pr(X \leq q_x(p)) = p$, and analogously for Y. Thus if X *FSD* Y then for all social welfare functions in W_1, the expected social welfare from X is at least as great as that arising from Y, with strict inequality for some w. One should note that while X FSD Y implies that the mean of X will be less than that of Y, this is not a sufficient condition for FSD.

The distribution of X second order stochastically dominates Y, *X SSD (second order stochastically dominates) Y, if:*

$\int_{-\infty}^{x} F(t)dt \geq \int_{-\infty}^{x} G(t)dt$ $\forall x \in \boldsymbol{Z}$, with strict inequality for some x (3)

This is equivalent to:

$\int_{0}^{p} q_x(t)dt \leq \int_{0}^{p} q_y(t)dt$ $\forall p \in [0,1]$, with strict inequality for some p (4)

If X SSD Y, then for all social welfare functions in W_2, the expected social welfare form X is at least as great as that arising from Y, with strict inequality for some w. It is important to note that FSD implies SSD, but that SSD is consistent with any ranking of the means of X and Y.

In order to test for FSD we proceed as proposed by Maasoumi and Millimet (2005) and define the following functionals of the joint distribution:

$$d = \min \sup_{x \in Z} [F(t) - G(t)]dt \,, \tag{5}$$

$$s = \min \sup_{x \in Z} \int^{x} [F(t) - G(t)]dt \,. \tag{6}$$

For any x_q, one can define the empirical equivalent of F and G as:

$$\widehat{F}_N(x_q) = \frac{1}{N} \sum_{i=1} I(X \leq x_q)$$

$$\widehat{G}_N(x_q) = \frac{1}{N} \sum_{i=1} I(X \leq x_q)$$

where I is an indicator function, and:

$$\widehat{d} = min\{max\{d_1\}, max\{d_2\}\}, \tag{9}$$

where

$$d_1(x_q) = \widehat{F}(x_q) - \widehat{G}(x_q) \tag{10}$$

and

$$d_2(x_q) = \widehat{G}(x_q) - \widehat{F}(x_q).$$

Then if for any xq_q, where $q = 1, \ldots, Q$, $max\{d_1\}>0$ and $\widehat{d} \leq 0$ (to a statistical degree), then *X FSD Y*.

To test for *SSD* one analogously defines the empirical equivalent of *s* as:

$$\widehat{s} = min\{max\{s_1\}, max\{s_2\}\} \qquad (11)$$

where

$$s_{1q} = \sum_{i=1} d_1(x_i) \qquad (12)$$

and

$$s_{2q} = \sum_{i=1} d_2(x_i) \qquad (13)$$

Then X SSD Y if $max\{s_1\}>0$ and $\widehat{s} \leq 0$ (to a statistical degree).

The underlying asymptoticistributions of the sample-based test statistics utilized are unknown and hence we rely on bootstrapping methods to test their significance as suggested by Maasoumi and Heshmati (2005). In this spirit, we bootstrap countries rather than specific observations. Moreover, we bootstrap separately from *X* and *Y* rather than from the combined sample as this would impose the null hypothesis only over the least favourable case of equal distributions, a subset of the composite boundary of the null. For each statistical test we use 500 replications and set *Q* to 500. All presented *p*-values are estimated sampling probabilities of the events under consideration.[6]

[6] As noted by Maasoumi and Heshmati (2005), this has the advantage of not imposing the null during re-sampling, but rather can be interpreted as bootstrap estimates of Bayesian posterior probabilities when all values of the *d* (*s*) are a priori equally likely.

As pointed out in the introduction, there is now a vast body of literature linking pollution and development levels. Although the exact shape of the relationship between a number of pollutant measures and income per capita is still a subject under debate (Dasgupta et al. (2002) and Bradford et al. (2005)), there is a consensus according to which there undoubtedly exists some sort of a relationship. We thus also examine *conditional* distributions of our pollution measure, which allows us to compare environmental quality across countries/time once income differentials are controlled for. Following Maasoumi and Heshmati (2005) this is done by estimating:

$$p_i = \begin{cases} \alpha_x + \sum_{j=1}^{3} \beta_{jx} GDPPC_i + \varepsilon_{it} & i \in X,\ i = 1,\ldots,N \\ \alpha_y + \sum_{j=1}^{3} \beta_{jy} GDPPC_i + \varepsilon_{it} & i \in Y,\ i = 1,\ldots,M \end{cases} \tag{14}$$

where p_i is the footprint measure in a country i, and ε is the error term. After the estimation of (14), one can construct estimated pseudo-residuals inclusive of the intercepts, $\hat{\tilde{\varepsilon}} = \alpha_k + \hat{\varepsilon}_i$, where $k = x,y$, and then conduct stochastic dominance tests on the distribution of the pseudo-residuals across time periods, and across regions at a given point in time. By purging the effects of income from pollution, one is able to eliminate changes in the distribution of environmental quality due to economic wealth. In what follows we will refer to this measure as conditional net footprint.

4.0 Results

In the top panel of Table 2 we first display the p-values of our FSD and SSD tests for the comparison of the total developing country sample over time. One should note that the p-values indicate at what level of statistical significance the null hypothesis can be rejected. When using unconditional results on the net footprint variable, i.e., net footprint, not purged from income effect, there is no clear cut result. More specifically, while net footprint measures for 1961 second-order stochastically dominated (SSD) their 2000 counterparts, this is not a very strong result since, as we have already mentioned before, SSD is a weak criterion which does not even necessarily imply that mean net footprint values in 1961 were smaller than in 2000.

Table 2: Stochastic Dominance Results

	Net Footprint			Conditional Net Footprint		
Across time						
	$d_{1,max}$	$d_{2,max}$	$\widehat{d}$	$d_{1,max}$	$d_{2,max}$	$\widehat{d}$
1961-2000	0.6	0.2	0.2	0.0	1.0	0.0
1961-1980	0.4	0.2	0.2	-0.2	0.8	-0.2
1980-2000	0.2	0.4	0.2	-0.2	1.0	-0.2
	$s_{1,max}$	$s_{2,max}$	$\widehat{s}$	$s_{1,max}$	$s_{2,max}$	$\widehat{s}$
1961-2000	96.8	0.0	0.0	-0.2	455.6	-0.2
1961-1980	89.8	0.0	0.0	-0.2	286.0	-0.2
1980-2000	17.2	45.0	17.2	-0.2	-0.2	444.4

	Net Footprint			Conditional Net Footprint		
Across countries						
	$d_{1,max}$	$d_{2,max}$	$\widehat{d}$	$d_{1,max}$	$d_{2,max}$	$\widehat{d}$
Caribbean vs RoDW	*0.07*	*0.66*	*0.072*	*0.57*	*0.42*	*0.42*
Caribbean vs SSA	*-0.02*	*0.90*	*-0.02*	*0.05*	*0.95*	*0.05*
Caribbean vs East Asia	*0.0*	*0.63*	*0.0*	*0.0*	*1.0*	*0.0*
Caribbean vs South Asia	*-0.167*	*0.800*	*-0.167*	*0.0*	*1.0*	*0.0*
Caribbean vs Latin America	*0.0*	*0.83*	*0.0*	*0.47*	*0.53*	*0.47*
Caribbean vs MENA	*0.63*	*-0.03*	*-0.03*	*0.08*	*0.83*	*0.08*
	$s_{1,max}$	$s_{2,max}$	$\widehat{s}$	$s_{1,max}$	$s_{2,max}$	$\widehat{s}$
Caribbean vs RoDW	*-0.01*	*38.56*	*-0.01*	*0.0*	*28.69*	*0.0*
Caribbean vs SSA	*-0.024*	*-0.024*	*-0.024*	*0.0*	*67.13*	*0.0*
Caribbean vs East Asia	*-0.08*	*66.37*	*-0.08*	*0.0*	*250.5*	*0.0*
Caribbean vs South Asia	*-0.17*	*161.8*	*-0.17*	*-0.17*	*470.13*	*-0.17*
Caribbean vs Latin America	*-0.06*	*113.8*	*-0.06*	*0.63*	*-0.03*	*0.63*
Caribbean vs MENA	*93.13*	*-0.20*	*-0.20*	*-0.08*	*243.05*	*-0.08*

Notes: 'RoDW' refers to 'Rest of the Developing World' and 'MENA' refers to 'Middle East and North Africa'.

Moreover, none of the other bilateral comparisons across years led to dominance results in either the first or second order sense.

As has been mentioned earlier, there exists a vast body of literature linking pollution with income, and referred to as the Environmental Kuznets Curve (EKC). Although the shape of the relationship is still under debate, its existence is now a well recognized fact (Dasgupta et al., 2002). In this regard, testing pairwise net footprint measures across time, conditionally upon the income level, seems a natural corollary, since not taking account of the extent of economic development may lead to unfairly biasing results in favour of, or against, early developers, depending on the relationship. As can be seen from the top panel, condition on economic wealth leads unambiguously to results consistent with welfare improvements, in the first order stochastic dominance (FSD) sense, over the whole period under scrutiny, i.e. from 1961 to 2000, as well as over the two sub-periods (1961 to 1980 and 1980 to 2000).[7] These somehow contradictory results between unconditional and conditional results on our dominance tests confirm previous evidence on the significant association between footprint and income (Bertinelli et al., 2007). Whether one should favour the conditional or the unconditional measure of net footprint when measuring potential improvements across time may depend on whether one is solely interested in environmental quality or also in welfare improvements due to economic growth. If, for example, the association between net footprint and income detected is actually positive, a possible interpretation of this result would be that in levels, pollution (measured in terms of net footprint) has possibly worsened, but given the growth of income over the same period, overall welfare may have improved.

We also compare the Caribbean region's net footprint with other developing regions of the world. More precisely, in the lower panel of Table 2, we depict the p-values of our FSD and SSD tests of Caribbean countries relative to (i) the rest of the developing countries, (ii) Sub-Saharan African countries, (iii) Latin American countries, and (iv) Middle-East and North-African countries for the most recent year of our data,

[7] Note that over the first sub-period we have evidence only for SSD.

namely 2000.[8] As previously, we again make the distinction between unconditional and conditional stochastic dominance measures. One may want to note that in the descriptive statistics part of this study, we already highlighted the fact that net footprint measures have been for most of the period larger in the Caribbean countries, compared to the group of countries comprising the rest of the developing world (LDC other than the Caribbean). This result is partly reflected again in Table 2, where there is robust evidence, in a second degree stochastic dominance sense, that LDCs other than the Caribbean dominate the Caribbean country group in terms of welfare. This result is robust to conditioning on income differences, which highlights again other developing countries SSD such as the Caribbean territories with respect to their environmental quality.

In a further step, we have tested the Caribbean countries against other specific groups of developing countries. As can be seen, the Sub-Saharan African country group's net footprint distribution first order stochastically dominates the distribution of the Caribbean country group. Going back to the descriptive statistics in Table 2, this result is also consistent with a mean dominance of net footprint in Sub-Saharan Africa compared to the Caribbean over our entire sample period. Indeed, in Africa, net footprint has been, and indeed still is, negative, meaning that natural regeneration is still larger than pollution generation. However, given the the Caribbean's significantly higher level of income (i.e. GDP per capita is about three times as high in the Caribbean compared to sub-Saharan African countries in the year 2000), one may expect results to be more mitigated when purging net footprint from income. As can be seen from the p-values of the conditional tests in the same panel, the sub-Saharan African countries' net footprint measure still significantly stochastically dominates the Caribbean's, but now only in the second order sense.

Similarly, as for the sub-Saharan African country group, South Asian and East Asian country groups unambiguously dominate in a first order sense the Caribbean countries in terms of net footprint distribution. However, once we rerun our dominance test on net-of-income net

[8] A complete list of countries is available in the Appendix.

footprint, no statistically significant dominance can be drawn from these pairwaise country group comparisons. Finally, the only country group which can be shown to be significantly dominated by the Caribbean in the second degree sense is the Middle East and North African country group. Indeed, for these countries, it can be deduced from the descriptive statistics that they have been facing important growth rates in terms of GDP per capita, but above all, of the net footprint measure, for the period under scrutiny.[9] Thus, in the latest available year that we observe, we find robust evidence for SSD of Caribbean countries over Middle East and North African ones even in the conditional sense.

5.0 Conclusion

The environmental economics literature has been particularly booming over the last decade or so. In particular, there have been extensive efforts to assess how pollutant emissions may evolve with development. This type of research has notably (but not only) materialized in the so-called Environmental Kuznets Curve. The approach that has been generally adopted is the standard regression framework, measuring the impact of some economic development measure on a measure of pollutant. The drawback of this methodology lies in the fact that it only provides insights on the determinants of the mean evolution of the pollutant under scrutiny. In the present paper, we provide a complementary approach to compare environmental quality across time and countries, by using stochastic dominance statistics, allowing us to provide results in terms of the evolution and comparison of environmental quality, compatible with a broad number of welfare functions. Furthermore, our measure of environmental quality is broader than in most empirical studies, as it encompasses not only one particular pollutant, but the total consumption

[9] GDP per capita has grown by 79 per cent in this country group, and net footprint by 413 per cent, over the period 1961-2000. As a comparison, Caribbean growth rates have been 80 and 213 per cent respectively, over the same period.

of humankind, expressed in a common unit and netted out from nature's regeneration capacity.

Our results show that for Caribbean countries, although net footprint data point towards a welfare decrease, when one takes account of increases in economic welfare (proxied by income per capita), the conclusions are reversed and overall welfare has improved over the whole period under scrutiny, as well as over sub-periods. In addition, we show that although welfare has improved across time, Caribbean countries are still lagging behind the rest of the developing world, as well as most regional groups of developing countries, with the notable exception of the Middle East and North African countries. These results originate from a too slow increase in economic wealth, a too fast increase in consumption of natural resources or a combination of both. On a more general level, arguably our results indicate that the stochastic dominance approach can be a fruitful tool for evaluating environmental quality and hence can serve as an instructive policymaking instrument.

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APPENDIX
Country groups

Rest of the Developing World

Afghanistan, Albania, Algeria, Angola, Argentina, Bangladesh, Belize, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, Chile, China, Colombia, Congo, Costa Rica, Cote d'Ivoire, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Honduras, Hungary, India, Indonesia, Iran, Iraq, Jordan, Kenya, Korea, Laos, Lebanon, Lesotho, Liberia, Libya, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Russia, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Somalia, South Africa, Sri Lanka, Sudan, Swaziland, Syria, Tanzania, Thailand, Togo, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Vietnam, Yemen, Yugoslavia, Zambia, Zimbabwe

Caribbean

Cuba, Dominican Republic, Haiti, Jamaica, Trinidad and Tobago

Sub-Saharan Africa

Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Cote d'Ivoire, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe

East Asia

Cambodia, China, Indonesia, Korea, Laos, Malaysia, Mongolia, Myanmar, Papua New Guinea, Philippines, Thailand, Vietnam

South Asia

Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka

Latin America

Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela

Middle East and North Africa

Algeria, Egypt, Iran, Iraq, Jordan, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, Yemen