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SPATIAL POLARIZATION OF THE ECOLOGICAL FOOTPRINT DISTRIBUTION.

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The international allocation of natural resources is determined, not by any ethical or ecological criteria, but by the dominance of market mechanisms. From a core-periphery perspective, this allocation may even be driven by historically determined structural patterns, with a core group of countries whose consumption appropriates most available natural resources, and another group, having low natural resource consumption, which plays a peripheral role. This article consists of an empirical distributional analysis of natural resource consumption (as measured by Ecological Footprints) whose purpose is to assess the extent to which the distribution of consumption responds to polarization (as opposed to mere inequality). To assess this, we estimate and decompose different polarization indices for a balanced sample of 119 countries over the period 1961 to 2007. Our results points toward a polarized distribution which is consistent with a core-periphery framework.

Keywords: Polarization, Core-Periphery, Ecological Footprint

JEL code:

1. INTRODUCTION

In today's age of globalization, a nation’s geographical extent, its economic activities and its environmental pressures can differ greatly from each other. The Ecological Footprint (EF) is an environmental indicator that measures human demand on natural resources in terms of space. According to this indicator, some countries’ consumption embody land surfaces in excess of that nationally available, while other countries’ consumption require less land than nationally available. According to the EF indicator, the World’s Ecological Footprint exceeded the Earth's biocapacity in the early 80’s (Global Footprint Network, 2010). Hence, since scarcity of natural resources is no longer merely a distant possibility, natural resource based conflicts may arise from distributional patterns. Traditionally, *inequality* has been linked to conflict, however, in the last decade *polarization* has been argued to better predict tensions relating a given resource distribution (Esteban and Ray, 1994): an example of high inequality would be where the EF distribution has a wide range, and each country has a different EF, whereas an example of high polarization would be where the EF distribution consisted of two clearly defined antagonistic groups: one group of high-EF countries and another group of low-EF countries.

Hitherto, spatial distributional analyses of natural resource consumption have dealt with inequality (White, 2007; Steinberger et al., 2010; Hedenus and Azar, 2005; Dongjing et al., 2010; Duro and Teixidó-Figueras, 2013) rather than polarization[1]. This paper, however, considers distributional conflict such as the one which emerges from world-system analyses of the core-periphery relationship (Wallerstein, 1974-1989). A classical conflict in these terms is found in Ecological Unequal Exchange theories (Hornborg, 2011) in which, from a world-system analysis perspective, the global distribution of natural resources is somehow structurally determined: some countries are turned into mere agricultural feeding grounds, mere sources of raw materials for the industrial development at the centre of the system. As a result, resource flows are driven from peripheral countries towards core countries. In this framework, capital accumulation leads to polarized structures in world-systemic processes in which the world sharply divides between those countries which consume a great amount of land – high EF – and other countries that hardly reach sufficiency levels for their proper development – low EF. In such an approach, the primary research question is not that of EF inequality but that of EF polarization. This paper's aim is thus to identify and to empirically track polarization trends in the international distribution of natural resource consumption as measured by EF, using the most common polarization indices from 1961 to 2007.

In particular, the polarization indices considered capture clustering processes among countries, and the underlying distributional instability in terms of EF, by the use of a methodology widely accepted in the literature of distributional analysis: the polarization cardinal approach mainly developed by Esteban and Ray (1994), Esteban et al. (1999), Zhang and Kanbur (2001) and Duclos et al. (2004). In this paper, we intend to evaluate for the first time, as far as we are aware, the degree of polarization of resource consumption by country, and hence the underlying conflict as suggested by major measures in the literature. In consequence, we provide a wide empirical view of this issue. Additionally, our empirical strategy allows us to investigate some determinants associated with these polarization measures.

[1] Duro and Padilla (2008), for example, showed how a polarization approach to the analysis of CO_2 emissions distribution led to notable conclusions about the emergence of the two groups (Annex B countries and non-Annex B countries) in the Kyoto protocol.

The paper is organised as follows: the following section briefly describes the EF. Section Three investigates, in an intuitive way, the main differences between polarization and inequality. Section Four deals with the methodological aspects of polarization by presenting the different polarization indices used. Section Five discusses the main empirical results from those indices and finally, Section Six concludes the paper.

2. THE ECOLOGICAL FOOTPRINT.

The EF (Wackernagel and Rees, 1996) consists in turning around the carrying capacity question: instead of asking how many people can be fed in a given habitat (land), the EF considers how much land is needed to sustain the consumption and waste absorption of a given population using available technologies (Martinez-Alier and Roca, 2001). According to Ecological Footprint Network, if everyone in the world lived like an average resident of the USA or of the United Arab Emirates, more than 4.5 Planet Earths would be required to support humanity's consumption rates. If instead, the world's population lived like the average person in India or Zambia, humanity would use less than half the planet's biocapacity. EF is formally defined as the area of productive land and water ecosystems, located anywhere in the world, required to produce the resources consumed by a population and to assimilate its wastes. To do this, the EF considers different categories of bioproductive land useful for human societies[2]. In other words, what is being answered in the EF framework is how many hectares, each having the average biological productivity of the whole earth (global hectares), are needed to maintain the consumption of a given population. This includes household consumption as well as collective consumption (such as schools, roads, fire brigades, etc.) and waste assimilation (see Ewing et al., 2010a, b)

The suitability of EF for the proposed analysis stems from a tradition in the literature of world-system analyses: departing from the early work on structural economic inequalities driven by international trade in Latin America (Prebisch, 1950), the concepts of 'embodied labour' (Emmanuel, 1973) and structural relations of dependency between peripheries and cores (Frank, 1967) built what today is known as World-system analyses (Wallerstein, 1974-1989). At the same time, other similar but ecologically-based literature was being developed; Borgström (1965) and Catton (1982) conceptualized the idea of 'embodied land', that is to say the consumption of resources which might require more land area than is actually available in one's own national territory; Borgström called these 'ghost acreages' to emphasize the fact that some foodstuffs (such as meat or dairy products) consumed by rich countries were typically imported from poorer countries, something of which

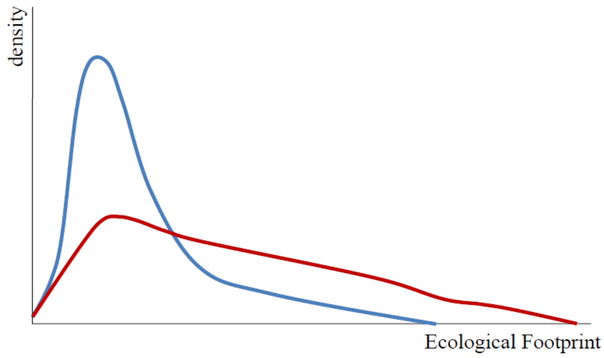
[2] Croplands, grazing lands, fishing ground, forests, built-up land and finally carbon land, which is the only land use type included in the EF exclusively dedicated to tracking a waste product. This latter is the amount of land needed to uptake CO_2 emissions.

consumers were unaware. By combining all of these concepts, Bunker (1985) assembled the first formulation of unequal *ecological* exchange. A few years later, Wackernagel and Rees (1996) popularized the EF which can be seen as a direct outcome of this tradition in the literature. Several researchers have found the EF measure useful in order to analyse asymmetrical flows in ecological terms (Anderson and Lindroth, 2001; Torras, 2003; York et al., 2003; Rice, 2007; Niccolucci et al., 2012, among others[3]).

3. POLARIZATION VERSUS INEQUALITY

One of the basic axioms of inequality measurement is the Pigou-Dalton principle which states that the inequality index should decrease when there is a progressive transfer.[4] Such equalising transfers would appear in the form of a concentration of the EF density function (Figure 1 represents a hypothetical distribution). We could say that the blue distribution is the outcome of Pigou-Dalton transfers occurring in the red distribution, and so all Lorenz-based Inequality indices will register a reduction.

Figure 1. A global distribution concentration lowers Inequality



Source: Present authors.

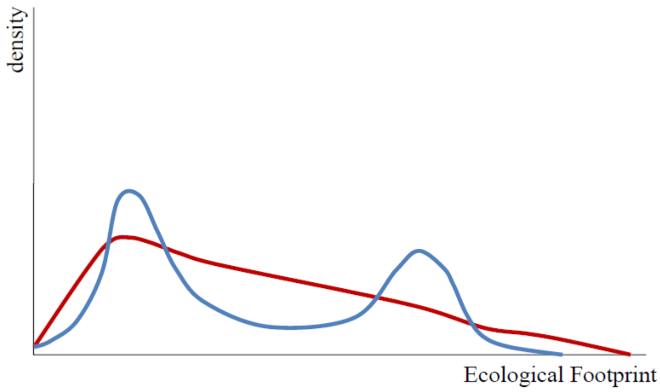
However, if we now consider the same behaviour in the distribution, but occurring at different local points (Figure 2) instead of globally as above, we see that inequality will be lower again (since still being reached by Pigou-Dalton transfers). Now, two antagonistic groups are clearly defined, each

[3] This work is remarkable as it focuses on capturing unequal Ecological Exchange by using the 'framework of 'social metabolism' (Fischer-Kowalsky, 1998) through the Material Flow analysis. Some examples are Pérez-Rincón (2006), Giljum and Eisenmenger (2004), Dittrich and Bringezu (2010, 2012). Their results generally show that Core countries import much more weight (materials) than they export, whereas in the peripheral countries, the opposite applies.

[4] *Pigou-Dalton Principle of transfers*: any transfer from an observation (country) with a high level of a variable to an observation (country) at a lower level (which does not invert the relative rankings) should reduce the value of the inequality index.

with a clear sense of itself and of the other (Esteban and Ray, 1994). This is the result of the combination of two different and contradictory processes; on the one hand, there is an *identification* process, which entails an equalisation process through the local convergence of observations of a group and on the other hand, there is an *alienation* process which, in contrast, captures the inequality between the groups identified. Indeed, the inequality approach actually captures only one part of the polarization framework, that of alienation — it does not consider the sense of identification which is a critical differentiating factor. Clearly, there may be some changes which could be considered as both inequality and polarization enhancing if, for instance, the two groups represented in Figure 2 increased the distance between them (without changing the within-group cohesion), inequality and polarization would presumably both increase.

Figure 2. Local distribution concentrations lower inequality and increase polarization



Source: Present authors.

Therefore, the crucial difference between inequality and polarization is that polarization takes into account the Lorenz contractions in a global sense (Figure 1) or in a local sense (Figure 2), or in other words, the underlying axioms of the inequality measurement (or equivalently, second-order stochastic dominance for mean-normalised distributions) fail to adequately distinguish between "convergence" to the global mean and "clustering" around "local means" (Esteban and Ray, 1994). As previously stated, this paper will analyse to what extent a clustering process around local means actually exists, this being consistent with the core-periphery hypothesis.

4. MEASURING POLARIZATION: INDICES

Since the initial work of Esteban and Ray (1994) and Foster and Wolfson (1992 [2010]), different statistical measures have been proposed to analyse polarization. We will focus on those that have recently received more attention in empirical work. These are EGR indices (Esteban et al., 1999) and the ZK index (Zhang and Kanbur, 2001) defined for discrete distributions,[5] and DER indices (Duclos et al., 2004), which are designed for continuous distributions and significantly complement the previous ones.

Before introducing the particularities of these different families of indices, we will briefly describe the general features from which they are derived.[6] Doing so will allow us to have a clearer picture of what the proposed indices actually measure. According to Esteban and Ray (1994), the basic features of polarization are:

1. The issue is that of groups. An isolated observation should have little weight.
2. There must be a high degree of homogeneity within the groups, i.e. a great sense of feeling of identity.
3. There must be a high degree of heterogeneity between groups, i.e. a great sense of feeling of alienation.
4. There must a small number of significantly sized groups.[7]

In order to make this notion plausible, these authors axiomatised these features and proposed the family of ER indices (Esteban and Ray, 1994) which formally sum all antagonisms between all countries (notation already adapted) of the different groups, where antagonism is viewed as a combination of inter-group alienation, and identification with the group itself:

$$ER(\alpha) = \sum_{i=1}^{n} \sum_{j=1}^{n} p_i^{1+\alpha} p_j \left| \frac{e_i}{e} - \frac{e_j}{e} \right|, 1 \leq \alpha \leq 1.6 \qquad (1)$$

where p_i and p_j are the relative populations of countries i and j; and e_i and e_j are the EF per capita of both countries, while e is the average EF per capita. Notice that if we removed the p_i^{α} of the expression (1), the result would be the Gini coefficient. Indeed, it is precisely the fact that population weights are raised to a power greater than one which constitutes the real difference between inequality and polarization. The term p_i^{α} stands for the sense of identification and so accounts for the clustering

[5] Ezcurra (2007) and Duro and Padilla (2008) calculate EGR indices to analyse CO_2 emission distribution, while Duro and Padilla (2013) extend such analyses by also calculating ZK indices.

[6] Insofar as single-dimensional approaches are considered, we are assuming that only one variable (here EF) defines the notion of the group, the notion of identification and the notion of alienation at the same time. In contrast, multidimensional approaches would allow variables other than EF (ethnicity, religion, etc.) to define groups.

[7] Therefore, the maximum potential conflict according to polarization happens when there are two equally sized groups. Actually, there are some indices such as those proposed by Foster and Woflson (2010) that are limited to measuring bipolarization. Additionally, the literature of conflict also distinguishes Polarization from Fractionalization measures, which, in contrast, increase the level of conflict as the number of groups increase (see Esteban and Schneider, 2008).

effect by which each country identifies with its own group. The second term, meanwhile, captures the alienation between countries i and j. Hence, $p_i^{\alpha}\left|\frac{e_i}{e}-\frac{e_j}{e}\right|$ is the antagonism felt by each country of group i with respect to each country of group j (Esteban, 2002). Thus, α is a parameter measuring the degree of polarization sensitivity (or the polarization aversion), whose construction defined as $1<\alpha<1.6$.[8] The larger the value of α, the greater the importance we are giving to the clustering of groups of countries and so the greater the departure from inequality measurement will be.[9]

However, the ER indices presuppose that groups are already defined and so the only thing needed to be defined is the parameter α, so that we can measure the degree of polarization between the existing groups. But, in most of practical situations, such as the one discussed here, distributions are not grouped *ex ante*. Thus, in order to make the equation functional (1), it is necessary to choose a number of groups to work with and also a mechanism to define these groups. To address this technical problem, Esteban et al (1999) proposed the EGR indices, by which the groups are defined endogenously using the algorithm of Davies and Shorrocks (1989), which basically consists in delimiting the groups in such a way that the Gini index value of the original distribution f corresponding to the within group inequality is the minimum possible[10]. In other words, the groups are delimited in such a way that the average within-group cohesion is maximal. In doing so, the algorithm yields an optimal simplified distribution ρ* (simplified because data is grouped according to the n groups,[11] where the minimum loss of information is guaranteed with respect the original distribution f. However, simplifying the distribution to such an extent requires altering of the measurement of polarization ER (1) for the degree of cohesion within the defined groups. Following the existing literature, we will refer to this correction as the error term of the polarization index. Thus, the family of EGR indices is defined as:

[8] For the derivation of the limits of α in the ER index, see Esteban and Ray (1994).

[9] In order to understand the role of α, consider a situation where the population (or the countries) are divided into three groups, with the two higher groups being the same size. Then suppose that these two groups fused into only one group (so that the population now forms two groups). Then, we would expect the polarization measure to increase as long as the third group is considered large enough. However, if the third group is considered small, the polarization measure should decrease. The "size" of the third group depends on the parameter α, and so it measures aversion to polarization.

[10] Such algorithms were designed in the context of income inequality analyses, where data from official publications were often grouped. However, it is important to bear in mind that there are no unanimous criteria to establish the precise demarcation between groups in a given distribution.

[11] Think of simplified distribution as the countries that have been grouped into a small number of categories such as the rich and the poor, or here, the high EF countries and the low EF countries (or the middle EF countries). Indeed, this simplification is what most people use informally when comparing distributions. Such informal descriptions can be seen as the simplified versions of the original distribution.

$$EGR(\alpha) = \sum_{i=1}^{n}\sum_{j=1}^{n} p_i^{1+\alpha} p_j \left|\frac{e_i}{e} - \frac{e_j}{e}\right| - \beta\left[G(f) - G(\rho^*)\right], 1 \leq \alpha \leq 1.6 \quad (2)$$

which consists of the ER index in the first term being corrected by the degree of cohesion of the defined groups in the second term, the error term.[12] *G(f)* is the Gini index of the original distribution and *G(ρ*)* is the Gini index of the optimal simplified distribution, or what would be the *between* group inequality. Therefore, the difference between both Gini indices approximates the *within* inequality (the level of cohesion within endogenous groups), and so, the higher the within group dispersion, the lower the polarization of a given group configuration. Finally, β is a free parameter measuring the sensitivity of such within-group cohesion. Following Esteban et al. (1999), Ezcurra (2007) and Duro and Padilla (2008, 2013), the parameter can be fixed as $\beta=1$ in the empirical analyses.[13]

In the empirical application of EGR indices, the number of groups is left to the discretion of the analyst. However, it should be understood that a high number of groups is meaningless in the context of polarization; empirical literature actually suggests up to four groups into which the distribution can be divided. Indeed, as we increase the number of groups, the simplified distribution becomes more accurate (so the error will be lower), but less sharp and useful. It should be taken into account that the decrease in error as the number of groups increases (the increase of the *within* cohesion) is non-linear; hence, the degree to which polarization decreases due to having a greater number of groups, is not compensated by the degree of greater cohesion within the groups. Therefore, the particular behaviour of the polarization measure taken together with its error term can be very useful in suggesting the number of groups that best define an appropriate representation of the distribution analysed in terms of groups (Esteban, 2002).

The main advantage of the EGR family of indices is that they were axiomatically derived from a behavioural model, and so their results are precise as to what they measure. For this reason, an interesting particularity of these indices is the endogenous grouping of the distribution by which the polarization is estimated. Nonetheless, it might be also interesting to calculate another family of polarization indices whose main particularity is the exogenous grouping in the distribution. These are the ZK indices (Zhang and Kanbur, 2001). As these authors suggest, debates on polarization may be understood within a framework where recognised and accepted groups are not driven by the variable being analysed (here EF), but by some other issue which might be socially determined. This might be

[12] The bipolarization measure proposed by Wolfson (1997) happens to be a particular case of the EGR index when α and β take the unitary value and the groups are defined by the median EF instead of the mean. Its main appeal however comes from its direct derivation from the Lorenz Curve.

[13] Besides as Duro and Padilla (2008) suggest, it seems more sensible, in terms of the internal scale of the measure, to establish $\beta=1$ since, at the end of the day, the definition of the three objects in EGR indices (*ER*, *G(f)* and *G(ρ*)*) are very similar.

the case if we apply our analysis to the theoretical framework of world-system analyses (Hornborg, 2011) in which some countries play a peripheral role in the world economy while others play a central role, independent of their EF distribution. Actually, the most typical division of countries in international debates is certainly is not along high EF and low EF lines but between developed, developing countries and, lastly, emergent countries. Therefore, it would be interesting to deal with these exogenous groupings by using the polarization approach and see whether there is a phenomenon of alienation between the common groups, at the same time as an identification process within them.

Once the groups have been exogenously determined (e.g. rich, emergent and poor), the ZK index simply calculates the ratio between the between-inequality (the inequality of the simplified distribution, now determined by groups defined exogenously from the EF distribution) and the within-inequality (existent inequality within those groups)

$$ZK = \frac{I(e)_B}{I(e)_w} \tag{3}$$

where $I(e)_B$ and $I(e)_W$ are the *between* inequality contribution and the *within* inequality contribution of the Inequality Subgroup decomposition (see Shorrocks, 1980; Shorrocks and Wan, 2005). Hence, the *between* inequality defined by the entropy measures popularized by Theil (1967, 1979), $E_0(\boldsymbol{e})$, is

$$I(e)_B = \sum_g^G p_g \log\left(\frac{e}{e_g}\right) \tag{4}$$

Where g denotes the group, p_g is the population share of group g, e the average EF per capita and e_g the average EF per capita of group g. According to Shorrocks and Wan (2005), the between inequality accounts for the total inequality that would exist if each member of the group had the average EF of that group. In the polarization framework being treated here, this component accounts for the alienation between groups since it is the inequality that would exist if the only source of inequality came from the inequality between the groups. Hence, as the between inequality increases, so does the ZK measurement. On the other hand, the within inequality component consists of the group weighted inequality within each group:

$$I(e)_W = \sum_g^G p_g \left[\sum_i^n p_i \log\left(\frac{e_g}{e_i}\right)\right] \tag{5}$$

The *within* Inequality accounts for the total inequality that would exist if all the groups had the same average. Within the polarization framework, however, it accounts for the within group cohesion. The greater the inequality within the groups is, the less the cohesion within the group and by construction, the lower the polarization.

It is important, however, to keep in mind that ZK indices are not as compelling as the EGR family since they do not satisfy some of the features described above for the latter. But, as can be intuitively seen in Expression (3), the features 2 (high degree of heterogeneity between groups) and 3 (high degree of cohesion) are properly satisfied. One of their drawbacks is that they may give unduly high values to isolated observations. Nevertheless, they might complement significantly EGR indices.

Finally, the last family of indices that will be considered in this analysis are the DER indices proposed by Duclos et al. (2004). DER family indices have been also derived axiomatically and share the same spirit as that of ER indices. Actually, their particularity and main difference from ER indices is that DER indices are designed for continuous distributions, while ER indices (and EGR indices by extension) are designed for discrete distributions. This basic difference leads to a slightly different interpretation of polarization.

DER indices are directly based on empirical density functions, which in practical terms means that the discontinuities of the groupings (either endogenous or exogenous) disappear. By way of example, consider a case of bipolarization with EGR indices where the groups have been delimited by the mean,[14] — what sense of identification do the countries that are just above and beyond the mean (and still so close together) have? In fact the countries mentioned, despite being grouped separately, may actually be closer to a member of another group rather than to one of their own. DER indices correct these unwelcome discontinuities by using a "window of identification" for each observation (country). In fact, the empirical distribution itself, estimated non-parametrically and so free of the assumption of the true (but unknown) distribution, is the criterion by which group size is determined, since a country is assigned to a particular group depending on its own particular distributional context. DER indices thus measure polarization from an *individual* alienation-identification perspective in which countries identify themselves only with those of similar EF, so that a country located in e_i experiences a sense of identification that depends on the density $f(e_i)$ at e_i. Hence identification and alienation are derived according to country's particular situation in the estimated empirical distribution.

Therefore, as in ER, DER indices are defined as the sum of all effective antagonism of e_i towards e_j, under f though:

$$DER = \iint f(e_i)^{1+\alpha} f(e_j) \left| e_i - e_j \right| de_j de_i, \text{ where } \alpha \in [0.25, 1] \quad (6)$$

Where, again, the first part of the expression accounts for identification, while the second accounts for alienation. An interesting particularity of this index is that their authors provide a decomposition of the measure in those same terms; i.e. identification, alienation and a third term capturing the correlation between the two. Hence:

[14] As actually is the case in the Davies and Shorrocks algorithm for two groups.

$$DER = a \cdot \iota \cdot [1 + \rho] \quad (7)$$

Where a is the average alienation ($a = \iint |e_i - e_j| dF(e_i) dF(e_j)$), ι the α-identification[15] ($\iota_\alpha = \int f(e_j)^{1+\alpha} de_j$) and ρ the normalised covariance between a and ι ($\rho = \frac{\mathrm{cov}(\iota_\alpha, a)}{\iota_\alpha a}$). This last term accounts for the co-movement of alienation and identification: an increase in alienation is associated with an increase in e distances, at the same time, an increased identification can emerge when there is a convergence around a certain point of distribution that was already highly concentrated. These changes taken together may reinforce one other (alienation may be higher at observations that have experienced an increase in identification) or they may counterbalance each other (a decrease in identification may involve an increase in alienation). Therefore, it is not possible to move these three factors around independently — after all, density describes the distribution of EF and these three factors are by-products of that density (Duclos et al. 2004).

The above approach is interesting because, again, it complements the previous polarization measures from a different perspective, in that the empirical distribution is used to define the phenomenon of identification-alienation. Furthermore, one could argue that in certain situations (including this one), where countries are the objects of analysis, polarization may stem from a more individual perception of distribution rather than from any arbitrary set of groups. In this way, as the authors have suggested, DER indices measure the 'pure polarization' of a distribution. Hence, it allows us to extend typical polarization analyses, based on explicit group definitions (either exogenous or endogenous), by exploiting the notion of *pure* polarization, where the identification-alienation distances are determined by a "polarization window" for each country.

5. Cross-country polarization in EF: main empirical results

The data used comes from the Global Footprint Network (2010) and covers 119 countries from the period 1961 to 2007, by using cross-country samples every ten years (1961, 1970, 1980, 1990, 2000, 2007). The countries in the sample amount to 90% of world population, 91% of the GDP and 82% of the World Ecological Footprint (2007).[16]

Since graphical intuition regarding polarization has clearly been linked with its own multimodality, before properly estimating polarization measures it might be useful to estimate the density functions of the per capita EF. However, it is important to keep in mind that this is just one factor of several in

[15] It is called α-identification because a depends on α. Notice also, that here *a* is twice the Gini coefficient (Duclos et al. 2004)

[16] See Appendix A2 for the list of countries sampled.

polarization. For instance, the distribution might become bimodal and still register lower polarization than a unimodal density. There is a *ceteris paribus* condition that might not hold for that density alteration. Indeed, the existence of more modes may also bring average alienation down (Duclos et al. 2004). Consequently, polarization indices are highly useful because they allow a non-ambigous analysis.

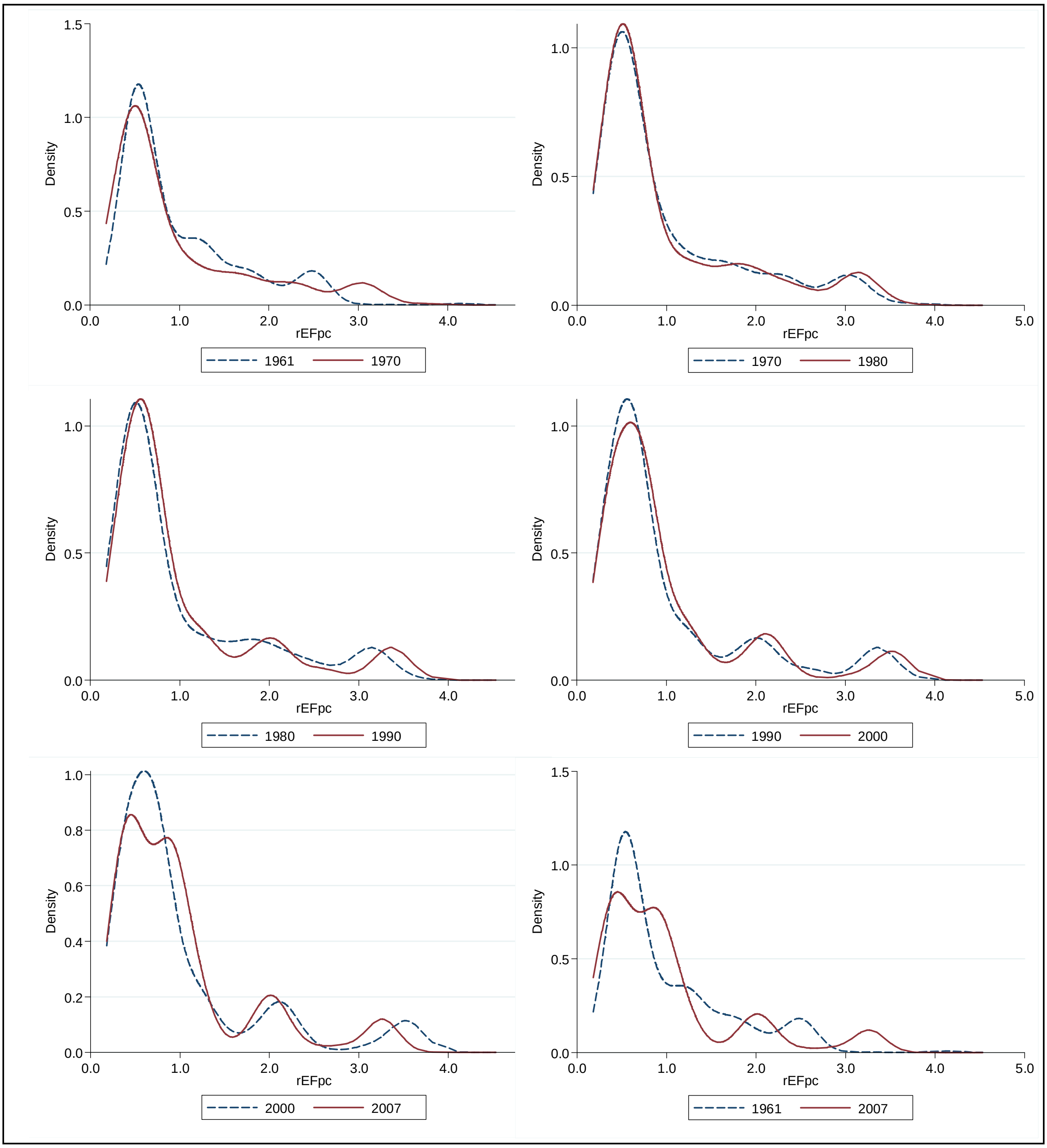
Figure 3 reproduces the empirical density functions of the various years, estimated non-parametrically using Gaussian Kernels.[17] Each graph includes the density functions of two consecutive periods in order to facilitate comparison and assist in understanding the change in the distribution over the period. The last graph compares 1961 to 2007 to see the overall change for the period analysed. Following the common practice of spatial distribution of environmental outcomes (Duro and Padilla, 2013; Ezcurra, 2007) and of income (Quah, 1997), each country's EF per capita has been normalised according to the average of the annual distribution, so that the comparison between distributions is not influenced by the global changes in EF levels over time. Thus a year's average is 1 by definition.

The results show that majority of the population of the countries sampled here registered a below average EF per capita during the whole period analysed. In terms of the modes of the distribution, it can be seen that in 1961 there was a main pole with a peak situated at 0.55 of the year's average where the mass of the population was clearly concentrated, but there was also a less defined and smaller pole (around 2.5 times the average) which in 1970 and 1980 became more clearly defined as it moved away from the main pole (alienation). Intuitively, such behaviour of the distribution should result in an increase in polarization from 1961 to 1980 as two modes appeared and consequently distanced themselves from one other. In 1990, however, something interesting occurred; while the smaller mode continued to alienate itself from the main mode (now at 3.5 times the mean), a third mode develops between the two (at 2.0 times the mean). This pattern becomes even more pronounced in 2000 as the mass of the main mode is used to better define the smaller ones. In this case, again intuitively, polarization decreases since there are more modes (more groups imply less average alienation between them) but, on the other hand, there is a tendency towards better identification and alienation from the main pole which should make polarization increase. Finally, in 2007 one sees that the two small modes, which have up to this point been alienating themselves from the main one, move

[17] The estimates are based on Gaussian kernel functions (see Quah 1997). The estimation of the density function performed assumes that each sampled observation gives some evidence of the underlying density within a 'window' around the observation (Cowell 2011). Then one can estimate density at EF value *e*, by specifying an appropriate Kernel function K (which itself has the properties of a density function) and a window width (or bandwidth) *w* and computing the function $\hat{f}(e) = \frac{1}{w}\sum_{i=1}^{n} K\left(\frac{e-e_i}{w}\right)$ where *K* here is the Gaussian kernel function and *w* has been determined endogenously using Silverman's method (1986).

back towards the distribution average, while the main mode seems to divide itself into two poles with a second main mode converging towards the distribution mean.[18]

Figure 3. Comparison of density functions of relative EF per capita 1961–2007



Source: Present authors from Global Footprint Network.

[18] This fourth populated mode is, in fact, China.

Hence, it is clear that the distribution of the EF per capita has experienced different clustering over the period analysed and, on some occasions, intuition allows us to make predictions about the resulting polarization of the distribution, as is the case in the period from 1961 to 1980, where polarization should increase. However, on some occasions, it is not that clear whether polarization should increase or decrease, as, for example, in the periods 1980 to 2007. In these cases, the polarization indices can make a non-ambiguous calculation of the whole sum of antagonisms in the distribution which helps in understanding what really occurs during polarization. The number of groups considered, together with the way in which they have been defined, plays a critical role in such evolution.

5.1 EGR INDICES

Table 1 shows the results obtained for the distribution of EF per capita between 1961 and 2007 for two and three groups according to different values of α (sensitivity to polarization). Groups are defined endogenously according to the Davies and Shorrocks (1989) algorithm[19]. Table 1 also shows the error term of the EGR index as a percentage of the Gini index, this error thus approximates the level of internal cohesion within groups, so that it informs how well those endogenously defined groups describe the distribution. Besides, the greater the error is, the lower the within-group cohesion and so, the lower the resulting polarization (see Equation 2).

Table 1. Polarization of EF per capita according to EGR family of indices

	EGR 2 groups				EGR 3 groups			
	α=1	*α=1.3*	*α=1.6*	ε/Gini	*α=1*	*α=1.3*	*α=1.6*	ε/Gini
1961	0.2065	0.1592	0.1213	18.88%	0.1947	0.1416	0.1033	6.50%
1970	0.2463	0.1942	0.1531	18.35%	0.2337	0.1766	0.1353	7.46%
1980	0.2549	0.2017	0.1599	18.51%	0.2318	0.1741	0.1324	9.26%
1990	0.2349	0.1845	0.1451	20.44%	0.2137	0.1589	0.1195	11.19%
2000	0.2138	0.1664	0.1294	22.71%	0.1884	0.1269	0.0833	9.53%
2007	0.1743	0.1311	0.0973	26.91%	0.1936	0.1332	0.0900	8.32%

Source: Present authors from Ecological Footprint Network.

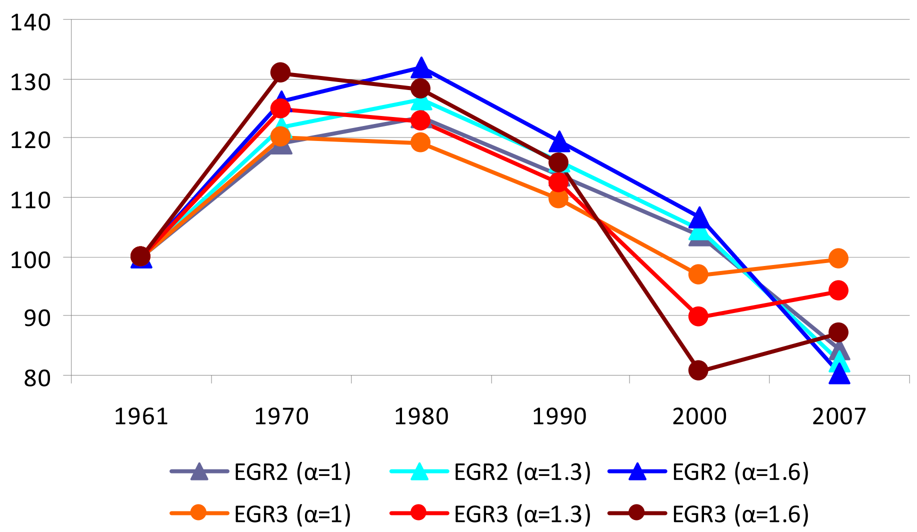
Although, as expected, moving from two to three groups decreases the error term, the two groups' distribution still exhibits the higher level of polarization, so that bipolarization apparently gives the more accurate description of the EF distribution as measured by EGR2: the results indicate an

[19] The specific groups of countries endogenously defined can be seen mapped in appendix A1

inverted U-shape over the period, regardless of the *α* used (figure 4): from 1961 to 1980 there is a clear increase in polarization of the two groups, which clearly coincides with the change in the density functions. In contrast, from 1980 onwards, the polarization decreases as a result, *inter alia*, of the increase of the error term, i.e. group cohesion diminishes along the whole period, though especially from 1980 onwards, yielding the decrease in the EGR index. However, despite the additional third group, the level of EGR3 registers a higher level in 2007 than EGR2. In this sense, the three groups simplification could be considered a better representation of the EF distribution for that year (when α=1 or α=1.3)[20].

The high explanatory power of the simplified distribution performed by EGR2 must be noted: as the error term indicates, most of the distribution behaviour is very well captured by the two-group simplification, especially until 1980 when more than 80% of the distributional pattern is captured by the simplified two-group distribution. In other words, one may say that the distance between countries below EF average and countries above EF average captures more than 80% of the total inequality in the distribution; this is quite significant in terms of the core-periphery framework.

Figure 4. Change of polarization according to the EGR family indices (1961=100)



Source: Present authors from Ecological Footprint Network

Apart from the error term, changes in polarization are also explained by variations in the size of groups (*p*), the identification, and the variations in the distance between groups (e_i-e_j) and the

[20] EGR4 was also calculated and it is available on request from the authors. However it was removed from the main text as it displays a less telling result: despite having a more accurate definition of groups (error term) the polarization index remains always lower than EGR2 and EGR3.

alienation (see previous section). Table 2 shows the changes that occurred both in terms of population weights and relative EF per capita for the different EGR endogenous groupings — this helps in understanding the driving forces behind the observed patterns. Focusing on the bipolar case (EGR2), we can see how Group 1 increased its population proportion (from 0.64 to 0.72) at the expense of the smaller group (Group 2, which reduced its population weight from 0.37 to 0.28). This works against polarization, since the small mass is transferring population to the greater one. At the same time, however, focusing on the average EF per capita of the groups, two subperiods may be distinguished: from 1961 to 1980, the Group 1 relative average shrunk at the same time that Group 2 increased from an average of 1.7 to 2.1; this is clearly consistent with the increase obtained in the EGR2 for that subperiod. Hence, alienation drove the polarization in such subperiod. Secondly, from 1980 on, both groups converge towards the average (normalized to 1) which, in addition to the general trend of the population proportion described, experienced a decrease in polarization. So, in general, according to EGR2, one observes how the identification factor tendency drives a reduction of polarization over the whole period, but changes in alienation apparently cause the inverted U-shape behaviour.

Table 2. Description of the endogenous groups' EGR indices: average EF per capita (in relative terms) and relative population of each group.

	Population share			**Relative EF per capita (e_i/e) (1)**		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
2 groups						
1961	0.637	0.363		0.577	1.741	
1970	0.692	0.308		0.541	2.032	
1980	0.702	0.298		0.53	2.107	
1990	0.709	0.291		0.554	2.088	
2000	0.72	0.28		0.579	2.079	
2007	0.719	0.281		0.616	1.981	
3 groups						
1961	0.526	0.274	0.2	0.522	1.076	2.152
1970	0.597	0.231	0.171	0.488	1.18	2.544
1980	0.606	0.223	0.171	0.484	1.169	2.605
1990	0.616	0.21	0.174	0.52	1.061	2.624
2000	0.407	0.413	0.18	0.439	0.87	2.566
2007	0.428	0.391	0.182	0.436	0.953	2.428

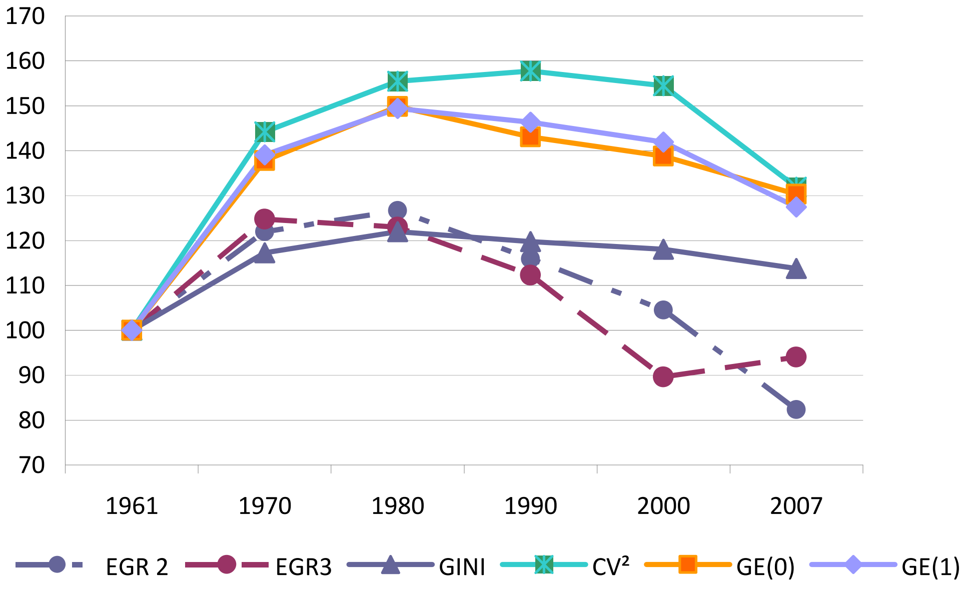
Source: Present authors from Ecological Footprint Network.

(1): By definition, each year's average is normalized to 1.

In the three-group simplification made by EGR3 there is a big group, containing almost half of the world's population and two smaller groups, which in 1961 are quite important in terms of population. From then on, the big group (formed by lowest per capita EF) increases its already high proportion at the expense of the two smaller groups (that is countries lowering their relative EF per capita, clustering to Group 1 from Group 2), a process which reached its maximum in 1990 when the big group contained 62% of the world population while the small groups (21% and 17%) equalised their weight with regards their initial population in 1961 (27% and 20%): this should, *ceteris paribus*, reduce the polarization index, and in fact it has if we look at EGR3 evolution. Then, the industrialization of China in the 1990's resulted in its EF per capita increasing dramatically and consequently it (and its high p_i) moved from Group 1 to Group 2; this resulted in two big groups (increasing polarization), though with a relative shorter distance between them (lowering polarization). Notice, however, how, in 2007, the new two big groups increased that distance between them yielding the three-pole scenario pictured by EGR3 in 2007.

For both practical and methodological reasons, EF inequality has also been calculated to be compared with the EGR polarization indices (Figure 5). While alienation enhances both polarization and inequality, Identification only enhances polarization while reduces inequality. If we compare the EGR2 trend with the Inequality trend, we can see that general pattern is similar, the creation of an inverted U-shape. This is because of the alienation process described among both groups. However, it is interesting to note that for the period 1980 to 1990, inequality grew at the same time that polarization decreased, coinciding with the jump observed in the error term of Table 1 (groups, endogenously defined, were less homogenous). Again in 2000-2007, if now we consider three-group simplification (EGR3) to be the most accurate representation of EF distribution, there was an opposing pattern between polarization and inequality. In this latter period, however, the opposite is true: inequality decreased while polarization increased; again the reason must be found in the identification factor within groups, in this case increasing their *within* cohesion. These results are important because in some occurrences the appearance of a decreasing inequality in natural resource consumption may incur an increase in the polarization of distribution (as the case between 2000 and 2007), or the opposite may occur, polarization might decrease at the same time as inequality increases (as seen for the period 1980-1990 if we measure inequality by CV^2).

Figure 5. Evolution of cross-country Inequality and polarization (1961=100)



Note: EGR (α=1.3 and β=1)
Source: Present authors from Ecological Footprint Network

5.2 ZK INDICES

In addition to the EGR indices, where the groups of countries are formed endogenously, it may be worthwhile to look at the polarization stemming from exogenous groups using ZK indices (Zhang and Kanbur, 2001). The interest of such an approach stems from the knowledge that, in many situations, debates on international issues does not divide the world in terms of high and low EF countries, but in terms of their income level. Probably the most common "simplified distributions" of countries are that of Rich-Poor countries and Rich-Emergent-Poor countries. Hence, the idea of ZK indices is to measure polarization in terms of such exogenously defined groups in terms of income: ZK2 for Rich and Poor countries and ZK3 for Rich, Emergent and Poor countries.[21]. Therefore, the underlying research question here is, again, to track whether there are alienation and identification processes according to ZK methodology, but now between rich-poor, rather than between endogenous groupings. We also consider to what extent the results obtained may complement EGR results.

Table 3 presents the results. Firstly, the usefulness of such income groups (simplified distribution) is remarkable in explaining the distribution of EF: the *between* inequality shows how a high share of the distribution is determined by the mean differences among these two/three groups. Focussing on ZK polarization, the results obtained (for both ZK2 and ZK3) once more show the same inverted U-shape

[21] Income based groups according to the classification made by World Bank. For the countries belonging to each groups, see Appendix A2. Again ZK4 has been calculated and is available on request. However, the results obtained are almost identical to ZK3, so that the fourth income group does not add any further polarization information.

with the turning point also between the decades 1980 and 1990. Indeed, on decomposing the ZK change by logarithmic differences, we see how the increase in ZK polarization is always driven primarily by the *between* effect (alienation between groups) whereas the decrease is shared by both the decrease in *between* and *within* factors. Notice, however, that the *within* factor is always pushing polarization downwards, so that the *between* group's component is the one causing the inverted U-shape which is finally observed in the development of this particular index (note the similarity to the EGR2 indices). Such similarity with EGR indices points towards the fact that polarization of natural resource consumption might, to a great extent, be driven by world income groups. Table 4 shows the changes in relative populations and relative EF averages.

ZK3 performs a higher level of polarization, not only because of that lower *within* component (higher identification), but also because of a larger *between* component (higher alienation). Consequently, the rich-emergent–poor grouping became telling earlier in terms of ZK polarization than did the rich-poor grouping. Comparing ZK polarization with inequality, again, it can be observed that the continued (although slight) increase of dispersion within income groups has been increasing inequality, while slowing down polarization. However, it is the alienation between groups that has mainly driven both trends. Hence, from this perspective, the high level of compactness of EF distribution around income-based groups is remarkable, while the alienation between groups represents the bulk of the distribution.

Table 3. Exogenous polarization as measured by ZK index for World Bank income classification and decomposition of changes by logarithmic differences

	Two-group polarization					Three-group polarization					Inequality	
	ZK(2)*	Between I. (%)		Within I. (%)		ZK(3)**	Between I. (%)		Within I. (%)		T(0)	CV^2
1961	2.6245	0.1298	(72%)	0.0494	(28%)	2.9611	0.1340	(75%)	0.0452	(25%)	0.1792	0.4436
1970	3.1934	0.1881	(76%)	0.0589	(24%)	4.5020	0.2021	(82%)	0.0449	(18%)	0.2470	0.6398
1980	3.2767	0.2057	(77%)	0.0628	(23%)	4.3965	0.2188	(81%)	0.0498	(19%)	0.2685	0.6896
1990	2.8984	0.1906	(74%)	0.0658	(26%)	4.6820	0.2112	(82%)	0.0451	(18%)	0.2564	0.6998
2000	2.3298	0.1741	(70%)	0.0747	(30%)	3.8083	0.1971	(79%)	0.0517	(21%)	0.2488	0.6853
2007	1.5846	0.1432	(61%)	0.0904	(39%)	2.3382	0.1636	(70%)	0.0700	(30%)	0.2336	0.5849
Logarithmic differences												
1961-1980	0.2220	0.4608	(208%)	-0.2388	(-108%)	0.3953	0.4903	(124%)	-0.0951	(-24%)		
1980-2007	-0.7265	-0.3623	(50%)	-0.3642	(50%)	-0.6314	-0.2905	(46%)	-0.3409	(54%)		
1961-2007	-0.5046	0.0985	(-20%)	-0.6030	(120%)	-0.2362	0.1998	(-85%)	-0.4360	(185%)		

Notes: * Two exogenous groups: Group 1 is the lower income and low middle income countries; Group 2 is the upper middle and high Income countries.

** Three exogenous groups: Group 1 is the low and lower middle income countries; Group 2 is the upper middle income countries; Group 3 is the high income countries.

Source: Present authors from Ecological Footprint Network.

Table 4. Description of the ZK indices for the exogenous groups: average EF per capita (in relative terms) and relative population of each group.

	Population share			**Relative EF per capita (e_i/e) (1)**		
	Group 1 (poor)	Group 2 (emergent)	Group 3 (rich)	Group 1 (poor)	Group 2 (emergent)	Group 3 (rich)
ZK2*						
1961	0.629	-	0.371	0.599	-	1.679
1970	0.645	-	0.354	0.533	-	1.852
1980	0.666	-	0.333	0.526	-	1.947
1990	0.686	-	0.314	0.555	-	1.972
2000	0.701	-	0.300	0.583	-	1.974
2007	0.708	-	0.292	0.626	-	1.908
ZK3**						
1961	0.629	0.119	0.253	0.599	1.327	1.845
1970	0.645	0.122	0.231	0.533	1.191	2.201
1980	0.666	0.126	0.208	0.526	1.292	2.343
1990	0.686	0.127	0.187	0.555	1.170	2.515
2000	0.701	0.127	0.173	0.583	1.139	2.585
2007	0.708	0.125	0.166	0.626	1.142	2.486

Notes: * Two exogenous groups: Group 1 is the lower income and low middle income countries; Group 2 is the upper middle and high income countries.

** Three exogenous groups: Group 1 is the low and lower middle income countries; Group 2 is the upper middle income countries; Group 3 is the high income countries. (1): by definition each year's average is normalized to 1.

Source: Present authors from Ecological Footprint Network

These results complement those obtained from the EGR indices. As in the case of endogenous groupings, it is shown that the EF distribution it is in fact a group issue rather than one of individual countries. Despite important differences in the methodology for capturing polarization, ZK indices clearly exhibit the role played by income groups in terms of determining the amount of land consumed.

5.3 DER INDICES

In Table 5, the results obtained by the estimation of DER indices (Duclos et al, 2004) are presented. However, it is important to keep in mind that DER indices are intrinsically different to the previous indices due to the fact that polarization does not stem from defined groups (either exogenous or endogenous), but from the individual perspective of each country in its particular empirical distribution context, so that group identification depends on the position of that country in the estimated distribution. More formally, a country located in e_i experiences a sense of identification that depends on the shape of the estimated density $f(e_i)$ at that point. Therefore, from this point of view, the polarization measured, despite sharing the same spirit as the previous calculations, allows a different interpretation of the same phenomenon: the polarization of the EF distribution is a by-product of the alienation of countries, each fuelled by its own particular sense of identification within the distribution. In other words, there are as many groups as there are countries in the sample.

One of the main advantages of DER indices that they allow decomposition in terms of alienation and identification as formally defined by the index (Expression 7). Hence, Table 5 also presents such decomposition, where polarization is the product of the average alienation, the average α-identification and (one plus) the normalised covariance between the two. Towards the bottom of Table 5, the logarithmic differences have been calculated in order to approximate the growth rates of DER and decompose them according to the development of these components.

The results point again towards the inverted U-shape with an increase in polarization for the first few decades of the sample (until 1980) and a decrease thereafter.[22] However, in contrast to previous indices, and as by-product of continuous distribution assessment, DER indices tend to register a polarization increase over the whole period.[23]. Focusing on the decomposition, a relatively high weight and stable α-identification can observed over the period — this clearly consistent with the low within-groups inequality found in the EGR and ZK. As logarithmic differences show, the inverted U-shape pattern is again mainly driven by alienation (here inequality as measured by Gini index) rather than by α-identification.

[22] The inverted U-shape pictured, however, is much more subtle than previous ones. This is a direct consequence of dealing with no discontinuities within groups.

[23] Notice that DER(1) is the only index in which the polarization of 2007 is lower than the level of 1961. Actually, according to DER(1) the increase 1961-1980 was 4% and the decrease 1980-2007 was 5%. This is a direct consequence of different levels of sensitivity to identification (the value of α). As this sensitivity is directly linked to an aversion to polarization, the higher the value, the more aversion to polarization is assumed and by construction more importance is given to the identification process. To appreciate this, consider the 1961 distribution as a concentration of the 2007 distribution. This concentration brings down alienation and increases identification. However, as long as α=1, concentration increases total polarization, but this is not the case for α<1.

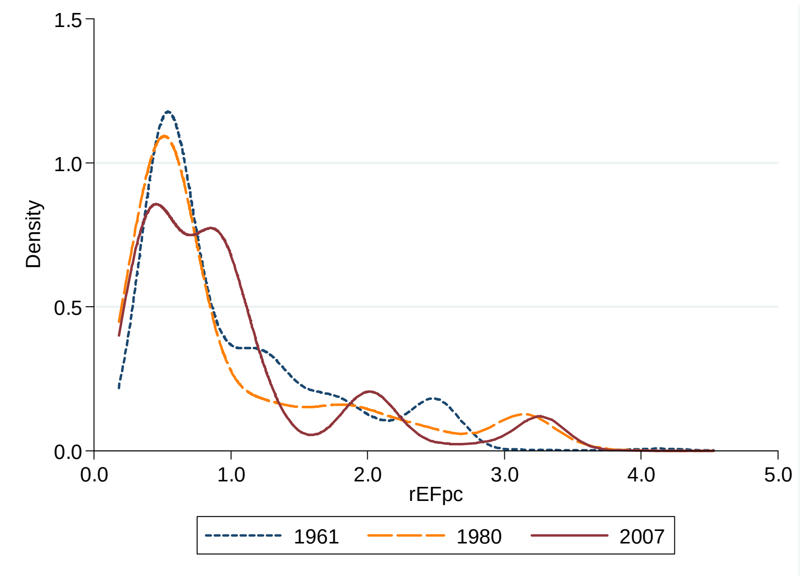
Table 5. EF Polarization as measured by DER indices and Alienation-Identification decomposition.

	DER (0.25)				DER (0.5)				DER (0.75)				DER (1)			
	DER	Alien.	α-Ident.	Corr.	DER	Alien.	α-Ident.	Corr.	DER	Alien.	α-Ident.	Corr.	DER	Alien.	α-Ident.	Corr.
1961	0.2646	0.3319	0.7983	-0.0014	0.2175	0.3319	0.6591	-0.0054	0.1837	0.3319	0.5554	-0.0032	0.1584	0.3319	0.4750	0.0047
1970	0.2971	0.3891	0.7930	-0.0372	0.2358	0.3891	0.6496	-0.0671	0.1937	0.3891	0.5430	-0.0834	0.1632	0.3891	0.4604	-0.0894
1980	0.3075	0.4048	0.7856	-0.0332	0.2422	0.4048	0.6384	-0.0628	0.1973	0.4048	0.5306	-0.0813	0.1649	0.4048	0.4480	-0.0907
1990	0.3013	0.3973	0.7971	-0.0487	0.2380	0.3973	0.6571	-0.0886	0.1949	0.3973	0.5539	-0.1145	0.1639	0.3973	0.4739	-0.1296
2000	0.2977	0.3917	0.7994	-0.0493	0.2354	0.3917	0.6594	-0.0887	0.1928	0.3917	0.5563	-0.1151	0.1621	0.3917	0.4765	-0.1318
2007	0.2898	0.3774	0.7888	-0.0268	0.2298	0.3774	0.6447	-0.0554	0.1879	0.3774	0.5394	-0.0771	0.1570	0.3774	0.4585	-0.0928
Logarithmic differences																
1961-1980	0.1503	0.1987	-0.0161	-0.0323	0.1074	0.1987	-0.0319	-0.0594	0.0714	0.1987	-0.0457	-0.0816	0.0405	0.1987	-0.0584	-0.0998
	100%	132%	-11%	-21%	100%	185%	-30%	-55%	100%	278%	-64%	-114%	100%	490%	-144%	-246%
1980-2007	-0.0593	-0.0700	0.0041	0.0066	-0.0524	-0.0700	0.0097	0.0078	-0.0491	-0.0700	0.0163	0.0045	-0.0492	-0.0700	0.0231	-0.0023
	100%	118%	-7%	-11%	100%	134%	-19%	-15%	100%	143%	-33%	-9%	100%	142%	-47%	5%
1961-2007	0.0910	0.1287	-0.0120	-0.0257	0.0550	0.1287	-0.0221	-0.0515	0.0223	0.1287	-0.0294	-0.0770	-0.0087	0.1287	-0.0353	-0.1021
	100%	141%	-13%	-28%	100%	234%	-40%	-94%	100%	578%	-132%	-346%	100%	-1479%	405%	1173%

Source: Present author from Ecological Footprint Network

If we retrieve the empirical density functions used above, specifically for the years 1961, 1980 and 2007 (Figure 6), we can see the basic densities from which DER have been estimated. The highest polarization level was reached in 1980 when alienation reached its highest level (the long-dashed function), at the same time as identification was relatively smaller than in 1961 and 2007. Actually, as can be seen in Figure 6, 1980 has a less peaked density, which should intuitively bring polarization down (low identification), however at the same time, the more modes there are in the distribution (as 1961 and 2007), the less the intrinsic alienation and consequently the lower the polarization. In this case though, the higher average identifications of 1961 and 2007 does not compensate for the greater alienation of 1980.[24]

Figure 6. Density Functions of relative EF per capita for years 1961, 1980 and 2007



Source: Present authors from Ecological Footprint Network.

Consequently, since in DER indices, alienation corresponds to the Gini index (recall Equation 7) and alienation explains the bulk of the changes in polarization according to this particular

[24] Notice that DER(1) is the only index in which the polarization of 2007 is lower than the level of 1961. Actually, according to DER(1) the increase 1961-1980 was 4% and the decrease 1980-2007 was 5%. This is a direct consequence of different levels of sensitivity to identification (the value of α). As this sensitivity is directly linked to an aversion to polarization, the higher the value, the more aversion to polarization is assumed and by construction more importance is given to the identification process. To appreciate this, consider the 1961 distribution as a concentration of the 2007 distribution. This concentration brings down alienation and increases identification. However, as long as $\alpha=1$, concentration increases total polarization, but this is not the case for $\alpha<1$.

family, the decomposition of DER indices allows us to conclude that EF polarization is mainly driven by the alienation factor (which in this case coincides with inequality).

6. Conclusions and Implications

The main aim of this article has been to analyse the spatial distribution of natural resource consumption (EF) from the perspective of polarization. The main interest of such an analysis is to assess to what extent the core-periphery relationships among countries have empirical support in the distribution of EF. From a core-periphery perspective,[25] capital accumulation would result in a world where natural resource allocation is structurally polarized between peripheral countries (which provide bioproductive land) and core countries (where high consumption patterns are thus maintained). In such a world, the EF distribution expected would be polarized, that is to say, driven by groups of countries rather by individual countries. Our results point in that direction.

From a methodological point of view, the distributional analysis of EF polarization has been dealt with the use of three families of polarization indices in order to improve the robustness of our conclusions: firstly, EGR indices, designed to analyse discrete distributions and whose main characteristic is the endogenous grouping of countries. Secondly, ZK indices which allow an exogenous definition of groups, and so where groups can be organised according to common classifications on the international scene. Finally, DER indices which, in contrast to the previous ones, are designed to analyse polarization of *continuous* distributions and can be decomposed in terms of alienation and identification. Despite how fundamentally different the measures are, all of them broadly measure the same concept, a combination of within-group cohesion (sense of identification) and between-group distance (sense of alienation). Their results appear to be consistent and complementary.

The first result we wish to highlight is that the EF distribution is a two- or three-group issue rather than representing differences among individual countries. Hence, the polarization framework produces much more telling results than does the inequality framework. This is a direct consequence of noticing that the EF distribution is almost totally explained by differences between two (three) groups of countries. In this regard, all indices showed an inverted U-shape for international EF polarization, this having been mainly driven by the concept of alienation (inequality between groups) rather than by identification within the already compacted groups (either endogenous or exogenous): the average distance between groups increased from 1961 to 1980 and decreased from then on. Meanwhile, identification tended to remain quite stable

[25] See Wallerstein (1974-1989).

(merely with a slight increase). Consequently, polarization and inequality tended to behave similarly (since alienation has a positive correlation with inequality while identification has a negative correlation). Nevertheless, inequality would not capture this distributional antagonism. Besides, EGR indices showed two periods (1980-1990) and (2000-2007) where inequality and polarization moved in opposite directions. The last period is particularly interesting in that EF inequality registered a decrease, while three-group polarization increased.

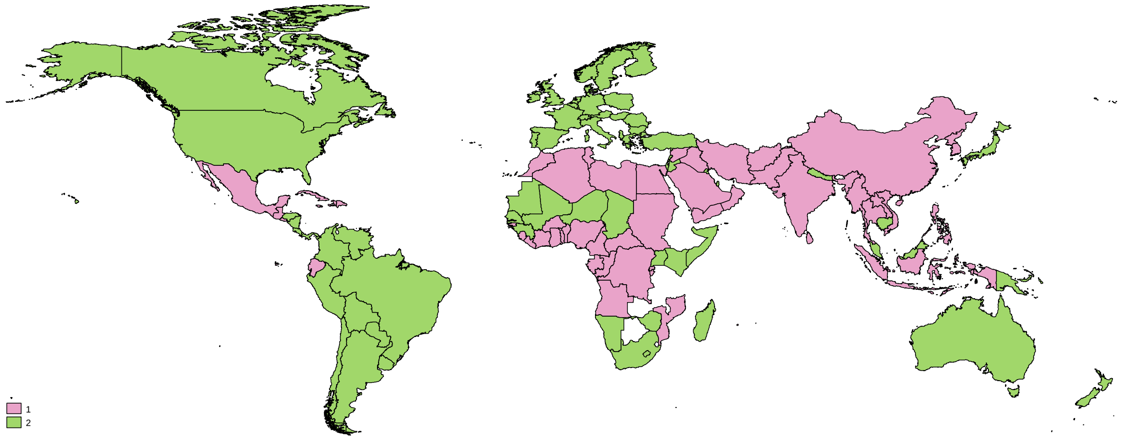
ZK indices show how the EF spatial polarization is tied to the distribution of income, which suggests that, in the end of the day, a country's income group determines the role that country plays in the natural resource flow through the global economy. Finally, DER indices, stemming from empirical density functions, confirm the polarization of the EF distribution with a high component of identification and an alienation over the period.

Therefore, the empirical evidence presented confirms that the EF distribution is mainly driven by the polarization concept. Such a conclusion pictures a global economy having an inherent conflict which stems from the sharp simplified distributions, and this is consistent with a core-periphery driven distribution.

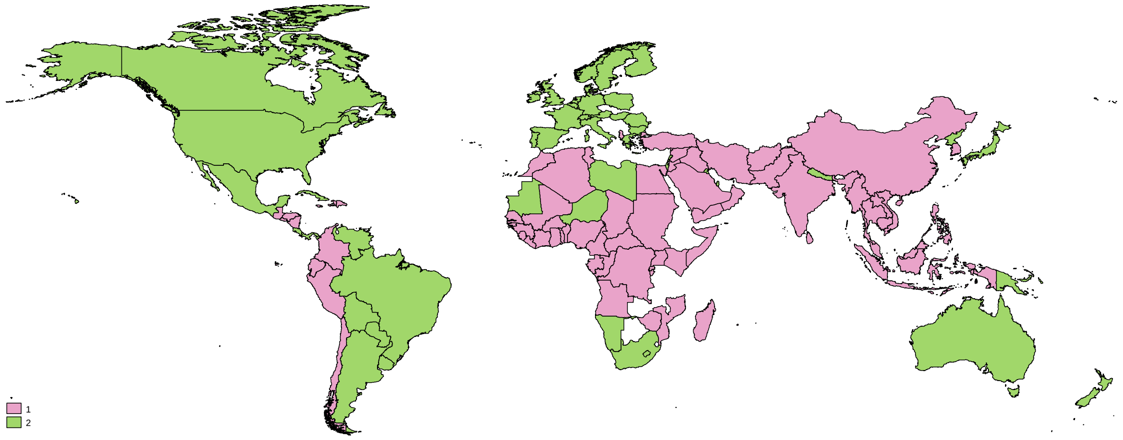
APPENDIX

A1. Endogenous groupings of countries for EGR indices.

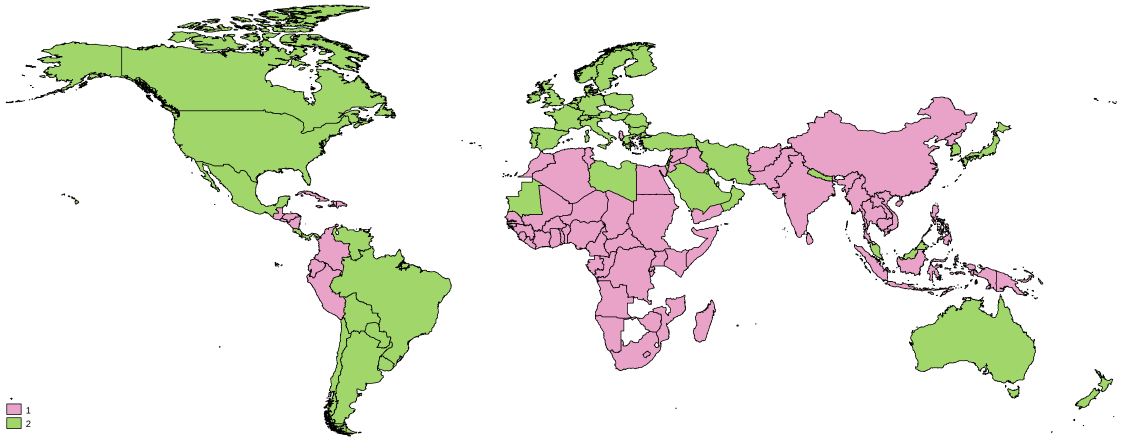
2 Endogenous groups (1961)



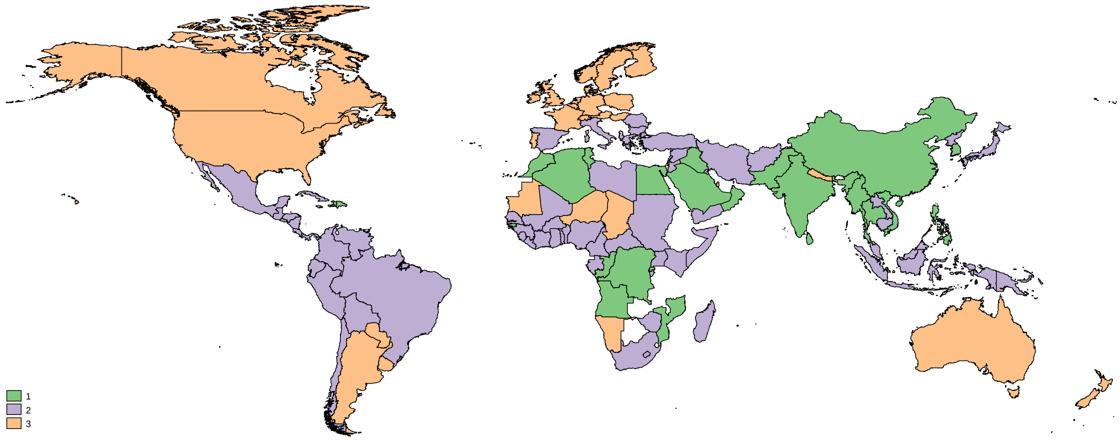
2 Endogenous groups (1980)



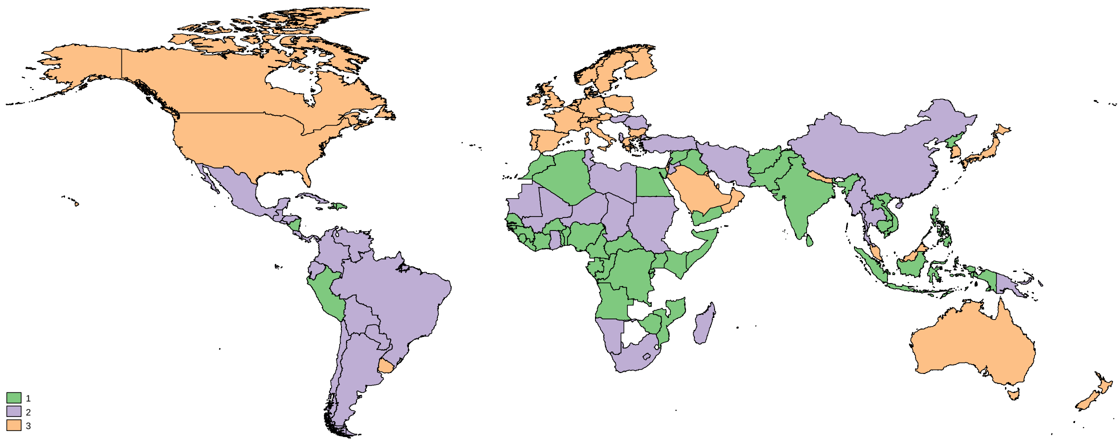
2 Endogenous groups (2007)



3 Endogenous groups (1961)



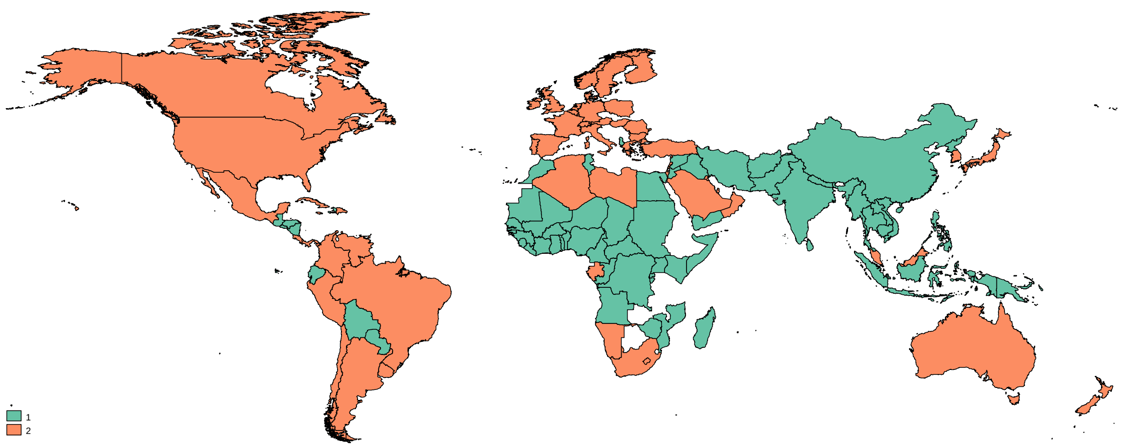
3 Endogenous groups (2007)



A2. Income Classification according to the World Bank

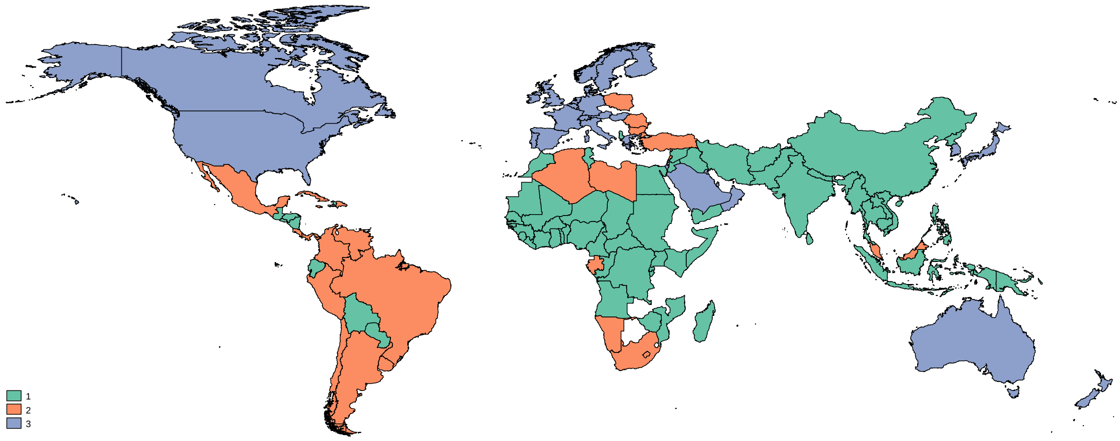
Low Income	Lower middle Income	Upper middle Income	High Income
Afghanistan	Albania	Algeria	Australia
Benin	Angola	Argentina	Austria
Burkina Faso	Bolivia	Brazil	Belgium
Burundi	Cameroon	Bulgaria	Canada
Cambodia	China	Chile	Denmark
Central African Rep	Congo	Colombia	Finland
Chad	Côte d'Ivoire	Costa Rica	France
Congo, DR	Ecuador	Cuba	Germany
Gambia	Egypt	Dominican Republic	Greece
Ghana	El Salvador	Gabon	Hungary
Guinea	Guatemala	Jamaica	Ireland
Guinea-Bissau	Honduras	Lebanon	Israel
Haiti	India	Libyan AJ	Italy
Kenya	Indonesia	Malaysia	Japan
Korea, DPR	Iran, IR	Mauritius	Korea, Rep
Lao PDR	Iraq	Mexico	Kuwait
Liberia	Jordan	Namibia	Luxembourg
Madagascar	Morocco	Panama	Netherlands
Mali	Nicaragua	Peru	New Zealand
Mauritania	Nigeria	Poland	Norway
Mozambique	Pakistan	Romania	Oman
Myanmar	Papua New Guinea	South Africa	Portugal
Nepal	Paraguay	Turkey	Qatar
Niger	Philippines	Uruguay	Saudi Arabia
Rwanda	Sri Lanka	Venezuela, BR	Singapore
Senegal	Sudan		Spain
Sierra Leone	Syrian Arab Republic		Sweden
Somalia	Thailand		Switzerland
Togo	Timor-Leste		Trinidad and Tob.
Uganda	Tunisia		United Kingdom
Vietnam			United States of A.
Yemen			
Zimbabwe			

2 Exogenous groups by income (ZK(2))*



* Group 1 is the lower income and low middle income countries; Group 2 is the upper middle and high income countries.

3 Exogenous groups by income (ZK(3))**



** Group 1 is the low and lower middle income countries; Group 2 is the upper middle income countries; Group 3 is the high income countries.

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