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Analysis

Spatial Polarization of the Ecological Footprint Distribution

J. Teixidó-Figueras *, J.A. Duro

Universitat Rovira i Virgili, Dept. Economia, CREIP, XREAP, Spain

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ABSTRACT

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 how strongly countries cluster together based on their Ecological Footprints: this is 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 point towards a polarized distribution which is consistent with a core–periphery framework.

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 embodies land surfaces in excess of that nationally available, while other countries' consumption requires 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 to a given resource distribution (Esteban and Ray, 1994, 2011): an example of high inequality would be where the EF distribution has a wide range (high variance), 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 with substantial intra-group homogeneity and inter-group heterogeneity: i.e. one group where all countries exhibit a high-EF and another group where all countries have low-EF. The underlying idea of polarization measurement is that groups rather than individuals are the decisive actors in large-scale conflicts (Esteban and Schneider, 2008). Such latent conflict might manifest itself in groups of countries that consume the most resources and at the same time in countries that scarcely consume them. Grouped countries have a greater possibility of developing their common interests than individual ones. Indeed, as Esteban and Ray (1994) suggested, there might be some economic and social phenomena for which the knowledge of the degree of clustering or polarization would be more telling than any measurement of inequality, in terms of conflict.

Hitherto, spatial distributional analyses of natural resource consumption have dealt with inequality (Dongjing et al., 2010; Duro and Teixidó-Figueras, 2013; Hedenus and Azar, 2005; Steinberger et al., 2010; White, 2007) rather than polarization. Duro and Padilla (2008), for example, showed how a polarization approach to the analysis of CO_2 emission distribution led to notable conclusions about the emergence of the two groups (Annex B countries and non-Annex B countries) in the Kyoto protocol. 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 resource consumption 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.

* Corresponding author.

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In particular, the polarization indices considered capture clustering processes among countries,[1] 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.

The paper is organised as follows: the following section briefly describes the EF. Section 3 investigates, in an intuitive way, the main differences between polarization and inequality. Section 4 deals with the methodological aspects of polarization by presenting the different polarization indices used. Section 5 discusses the main empirical results from those indices and finally, Section 6 concludes the paper.

2. The Ecological Footprint

The EF (Wackernagel and Rees, 1996) consists of 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 Global 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. 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. The latter is the amount of land needed to uptake CO_2 emissions. 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, and fire brigades) and waste assimilation (see Ewing et al., 2010a, 2010b). However, it should be taken into account that EF (as an indicator of the quantity of resource consumption) has some drawbacks. Indeed, any aggregate indicator will have both strengths and weaknesses, and this also applies to EF: it does not consider the demand of non-organic materials but for Carbon Footprint, it uses an intensive method of converting CO_2 emissions in global hectares as represented by the forests which are needed to absorb such emissions, it implicitly assumes the possibility of the substitution of different categories of environmental pressure, (see van den Bergh and Verbruggen, 1999).

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 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 (Andersson and Lindroth, 2001; Moran et al., 2013; Niccolucci et al., 2012; Rice, 2007; Torras, 2003; York et al., 2003, among others[2]).

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.[3] Such equalising transfers would appear in the form of a concentration of the EF density function, since the "rich" countries transfer part of their relative EF to "poor" countries so that most of the countries are concentrated now in smaller range of EF (Fig. 1 represents such a hypothetical distribution). We could say that the dashed distribution is the outcome of Pigou–Dalton transfers occurring in the red distribution, and so all Lorenz-based inequality indices[4] will register a reduction.

However, if we now consider the same behaviour in the distribution, but occurring at different local points (Fig. 2) instead of globally as the 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 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 Fig. 2 increased the distance between them (without changing the within-group cohesion), inequality and polarization would presumably both increase.

Therefore, the crucial difference between inequality and polarization is that polarization takes into account the Lorenz contractions in a global sense (Fig. 1) or in a local sense (Fig. 2), or in other words, the

[1] By clustering process we mean to what extent certain groups of countries distance between them at the same time that get closer within them. Those groups may be defined either exogenously (for example, income groups) or endogenously (with the algorithm of Davies and Shorrocks, 1989). It is remarkable that there are other clustering methods which could be used, however, considering the analysis proposed here, it results more consistent to use methodology from Inequality economics and Distribution.

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

[3] *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: consider an arbitrary distribution $x_{A:}= (x_1,\ldots, x_i,\ldots, x_j,\ldots x_n)$ and a number such that $0 < \delta < x_i \le x_j$; then being $x_B{:} = (x_1,\ldots, x_i-\delta,\ldots, x_j + \delta,\ldots x_n)$, the latter is set as more unequal than the former.

[4] Lorenz-based Inequality indices are all inequality indices that are consistent with Lorenz Curve (or Second Stochastic dominance, see Cowell, 2011). This involves satisfying Scale Independence ($I(x_1, x_2, x_3 \ldots x_n) \sim I(\lambda x_1, \lambda x_2, \lambda x_3 \ldots \lambda x_n)$), the Population principle ($I(x_1, x_2, x_3 \ldots x_n) \sim I(x_1, x_1, x_2, x_2, x_3, x_3 \ldots x_n, x_n)$) and Pigou–Dalton transfers (progressive transfers which do not invert the relative rankings, should reduce inequality).