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An empirical approach

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ABSTRACT

This paper analyses the gross inland energy consumption (EC) in the European Union countries (EU-15) taking in account the period 2005-2014. The standard tools in the measurement of income inequality such as Lorenz curves, Gini index, Generalized Entropy indices and Atkinson ones are applied. The empirical results, obtained through the decomposition of the generalized entropy indices, confirm that there are a small inward shift in the corresponding Lorenz curves, that the inequality distribution of EC across the EU-15 countries has decreased (the Gini coefficient falls from 44,27% in 2005 to 42,16% in 2014) and there are differences among the countries' clusters: Mediterranean, Continental, Nordic and Anglo-Saxon. This paper makes a good contribution to knowledge: firstly, it is innovative since it puts together energy consumption and inequality among the EU-15 countries, secondly, it uses a very up-to-dated database (Eurostat), and thirdly, it fills a gap in the literature.

Key words: Energy consumption, inequality measures, Lorenz curve, EU-15.

JEL Classification Codes: C14, C23

1. Introduction

One of the main important objectives of the European Union (EU) is focused on climate and energy efficiency. The *EU's Europe 2020 Strategy for smart, sustainable and inclusive growth*, identifies three key targets based on climate change and energy sustainability, the so-called '20-20-20' targets (7224/1/07 REV 1: Presidency Conclusions of the European Council of 8/9 March 2007): a 20% cut in greenhouse gas emissions (GHG) taking in account the 1990 levels; a share of 20% of EU energy consumption produced from renewable energy resources; a 20% improvement in energy efficiency on the EU primary energy consumption.

As a consequence, during the last decades, environmental and resource economists are concerned with non-income inequality measures which have become an important issue in developed countries. Modern societies are worried about different dimensions of inequality related to climate change such as GHG emissions (CO_2, …), gross inland EC-energy consumption, and others. Hence, the EU countries are facing a transforming moment and "Europe 2020" puts forward in reinforcing priorities: smart, sustainable and inclusive growth (European Commission, 2010). As part of these growth priorities, an important inititiative concerns a resource efficient Europe and distributive problems have become visible as the most important issues in the negotiations for adopting new agreements by policy makers.

The main focus of this paper is to spell out how the Lorenz curve and different inequality measures can be applied to study energy consumption in the EU-15. Gross inland energy consumption, also known as total primary energy supply, represents the quantity of energy necessary to satisfy the domestic consumption of a geographical entity under consideration (European Commision, 2016). This primary energy contains the final energy consumption and the energy that is consumed in the stages before the delivery to the final consumer. Hence, final energy consumption is the amount of overall energy actually consumed by the different economic sectors.

In the literature on energy economics, several studies have applied different tools of income distributive analysis to energy economics although most of them are focused on climate change and CO_2 emissions. Duro and Padilla (2006) provided a methodology for decomposing international inequalities in per capita CO_2 emissions into Kaya (multiplicative) factors and two interaction terms. They used the Theil index of inequality and analyzed the factors behind inequalities in per capita CO_2 emissions across countries, between groups of countries and within them.

Groot (2010) showed that standard tools in the measurement of income inequality, such as the Lorenz curve and the Gini-index, can successfully be applied to the issues of inequality measurement of carbon emissions and the equity of abatement policies across countries. These tools allow policy-makers and the general public to grasp at a single glance the impact of conventional distribution rules such as equal caps or grand fathering, or more sophisticated ones, on the distribution of GHG emissions. In addition, Duro (2013), using similar techniques, examined the role of changes in the countries' relative weights to explain the evolution of global international inequalities throughout the 1971-2007 period for some well-known environmental indicators. He focused on analysing the factors that could explain changes in CO_2 emissions' per capita inequalities using a variety of inequality measures such as the Gini index as well as the Theil family index to test the sensitivity of the results.

More recently, Mussini and Grossi (2015) studied the effects of changes in countries' ranking and per capita CO_2 emissions on CO_2 emission inequality over time. In order to reach this aim, they introduced a three-term decomposition of the change occurring in the Gini index applied to per capita CO_2 emissions when moving from an initial to a final per capita CO_2 emission distribution. They measured the change in per capita CO_2 emission inequality in Europe over the span period 1991–2011. The authors got their results using Lorenz and concentration curves.

Against the background of these applications of inequality measures to GHG emissions, this paper mainly contributes to the existing literature in two ways. Firstly, it is innovative in using final energy consumption; gross inland consumption is also important in order to have an indicator of the losses that occur throughout the transport, distribution and transformation stages in the delivery of final consumption energies. Secondly, inequality measures are introduced in order to study energy consumption; these measures allow us to rank the EU countries using the most recent data.

The rest of the paper is structured as follows. In Section 2, the main methodological aspects are described, namely the Lorenz curves, the Parade approach and the different inequality measures. Section 3 provides the main results obtained from the application of the above-mentioned methodology to gross inland energy consumption in the EU-15 countries. The final section summarizes the main findings and presents some recommendations for policymakers.

2. Measuring gross inland energy consumption inequality

Let us consider k countries and assume that, for every country i, the population n_i and gross inland energy consumption are known, with i=1,...,k and $n = \sum_{i=1}^{k} n_i$. Let EC_i be per capita energy consumption of country i and $p_i = n_i/n$ be its population's share. The Gini index (G) can be expressed as follows:

$$G = \frac{1}{2\overline{EC}} \sum_{I=1}^{k} \sum_{j=1}^{k} p_i p_j \left| EC_i - EC_j \right|$$

where $\overline{EC}$ is the average of gross inland energy consumption and the weights are the populations' shares. Gini coefficient ranges from 0 (perfect equality) to 1 (complete inequality). This index verifies the following properties: mean independence, population size independence, symmetry and Pigou-Dalton transfer sensitivity.

In addition, inequality can be made visible by means of Lorenz curves that show what percentage of total *EC* is held by the bottom *x*% of countries. This Lorenz curve depicts on the vertical axis the cumulative *EC* pitched against the cumulative share of the population on the horizontal axis. This methodology has been also applied to CO_2 emissions by Groot (2010). Thus, the Lorenz's approach is an important inequality graph usually used for international environmental analyses.

Alternatively, we use the Parade approach based on the famous story of the "parade of dwarf and a few giant" related by Pen (1971) according to which each country's gross inland consumption is representd by its "physical height". The countries are ranked in ascending order of gross inland consumption *x* ("height") and the typical pattern shape of the resulting profile is illustrated by a solid curve.

However, there are additional inequality's measures which are based on other points of view (Cowell, 2011). Among the most widely used, there is the family of the generalized entropy measures (*GE*) which is defined as:

$$\mathrm{GE}(\alpha)=\frac{1}{\alpha^2\text{-}\alpha}\left[\frac{1}{\mathrm{k}}\sum_{\mathrm{i}=1}^{\mathrm{k}}\left(\frac{\mathrm{EC}}{\overline{\mathrm{EC}}}\right)^{\alpha}\text{-}1\right].$$

Thus, when $\alpha = 0$, $\mathrm{GE}(0)=\frac{1}{n}\left[\sum_{\mathrm{i}=1}^{\mathrm{k}}\log\frac{\overline{EC}}{EC_i}\right]$; when $\alpha = 1$, $\mathrm{GE}(1)=\frac{1}{n}\left[\sum_{\mathrm{i}=1}^{\mathrm{k}}\frac{\mathrm{EC_i}}{\overline{\mathrm{EC}}}\log\frac{EC_i}{\overline{EC}}\right]$; and when $\alpha = 2$, $\mathrm{GE}(2)=\frac{1}{2\overline{EC}^2}\left[\frac{1}{\mathrm{k}}\sum_{\mathrm{i}=1}^{\mathrm{k}}(EC_i)^2\right]$. Therefore, measures from the *GE* class are sensitive to changes on the lower end of the distribution for α close to zero, are equally sensitive to changes across the distribution for α equal to one and are also sensitive to changes on the upper end of the distribution for higher values. As a result, the generalized entropy index has several inequality metrics as special cases. For example, *GE*(0) is the log deviation mean, *GE*(1) is the Theil index, and *GE*(2) is half of the squared coefficient of variation.

Finally, Atkinson proposed another class of inequality measures, A_ε, which have a weighting parameter ε considering different degrees of aversion to inequality. It is given by:

$$A_\varepsilon = 1 - \left[\frac{1}{k}\sum_{i=1}^{k}\left(\frac{EC_i}{\overline{EC}}\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}, \varepsilon \neq 1$$

$$A_\varepsilon = 1 - \frac{\prod_{i=1}^{k} EC_i^{\left(1/k\right)}}{\overline{EC}}, \varepsilon = 1.$$

Therefore, this index incorporates a sensitivity parameter (ε) which can range from 0 (meaning that the researcher is indifferent about the nature of the energy consumption distribution), to infinity (where we are concerned only with the consumption position of the very lowest group). The Atkinson index then varies between 0 and 1 and is a measure of the amount of social utility to be gained by complete redistribution of a given distribution. Atkinson argued that this index was a tool to incorporate Rawls' idea of social justice into the measurement of inequality. In practice, ε values 0.5, 1, 1.5 or 2 are used; the higher the value, the more sensitive the Atkinson index becomes to inequalities at the bottom of the distribution. This index varies between 0 and 1 and it is a measure of the amount of social utility to be gained by complete rearrangement of a given distribution.

Although the indices used in this paper have different characteristics, they help us to deep in the analysis of gross inland energy consumption. Gini index is more sensitivity to changes in observations located around the distributive mode whereas Theil family indices are characterized by greater sensitivity to changes in observations located at the lower end (or upper end) of the distribution ranking. In fact, all these indices support the hypothesis that it is important to examine the robustness of the results under varying inequality measures. After all, a situation of large energy consumption differences within the bottom, middle or top of the distribution are different "*types"* of inequality.

The generalized entropy (*GE*) class of indicators, including the Theil indices, can be decomposed across different partitions in an additive way into "within" and "between" components (Maio, 2007). We focus the next results on *GE*(0) and *GE*(1) decomposition. *GE*(0) can be decomposed as:

$$GE(0) = \sum_j \left(\frac{1}{N}\right) ln\left(\frac{Y}{Y_j N}\right) =$$

$$= \sum_j \left(\frac{N_j}{N}\right) GE_j + \sum_j \left(\frac{N_j}{N}\right) ln\left(\frac{N_j/N}{Y_j/Y}\right)$$

where Y is the total EC of all N countries in the sample, Y_j is the total EC of a subgroup with N_j members and GE_j is the value of $GE(0)$ for subgroup j.

Correspondingly, *GE*(1) can be expressed as:

$$GE(1) = \sum_j \left(\frac{Y_j}{Y}\right) GE_j + \sum_j \left(\frac{Y_j}{Y}\right) ln\left(\frac{Y_j/Y}{N_j/N}\right)$$

where GE_j is the value of $GE(1)$ for subgroup j.

Thus, we can separate the inequality measure into two components, the first of which represents the within-group inequality while the second term represents the between-group inequality.

3. Empirical results

The European Commission launched in February 2015 a new strategy for a resilient Energy Union with a forward-looking climate change policy. Obviously, this strategy is linked to energy consumption and its impact on GHG emissions, energy efficiency and renewable energy. New data about gross inland energy consumption of energy within the EU have been published by Eurostat (European Commision, 2016), showing an important decrease as a result of the global economic crisis rather than as a structural shift in the pattern of energy consumption. This new data set contains annual gross inland energy consumptions and final energy consumptions (both expressed in million tonnes of oil equivalent). This information allows us to compare the results and the main energy data for different countries.

As previously said, *EC* is the total energy demand of a country or region, including energy consumption by the energy sector itself, distribution and transformation losses and final energy consumption by end users.

In this paper, we concentrate on gross inland energy consumption in per capita terms (the unity being TOE- Tonnes of Oil Equivalent)). Table 1 gives an overview of the scores of these variables. All the data are from the span period 2005-2014 and was obtained from the Eurostat database.

A simple but effective way to examine inequality is to calculate decile ratios. The calculation is done by taking, for example, *EC* by the top 80% of countries and dividing that by the *EC* by the poorest 20% of countries (P80/P20). However, it ignores information about EC in the middle of the distribution, and does not even use information about the distribution within the top and bottom deciles.

Alternatively, all the information contained in Table 1 can be made visible by means of Lorenz curves (shown in Figure 1). As described earlier, the Lorenz curve shows the percentage of the total *EC* that is held by the bottom x% of countries (p_i), where countries are ranked by level of *EC* and the cumulative share of *EC* (q_i). The diagonals to the Lorenz curves turn out to correspond with equal *EC* distributions across countries. Table 2 shows that the value of the Gini coefficient for *EC* in EU-15 countries varies from 0,4427 in 2005 to 0,4519 in 2006 has and decreased since 2010 on.

As can be noticed there is a small shift of the Lorenz curve and the distribution inequality of *EC* across countries decreased (the Gini coefficient decreases from 44,27% to 42,16%). Though, since the distributions over time are so close to each other, we will concentrate on the distributions in 2005 and 2014 (the last year for which we have data). However, these differences are clearer when we base our results on the Parade approach. This graph plots per capita *EC* against cumulative percentage of countries. In this sense, it is important to point out that although inequality decreased over the period 2005-2014, *EC* was much higher at the bottom of the distribution in 2005 than in 2014.

Figure 1:
Lorenz curve: 2005 versus 2014. Variable gross inland energy consumption - EU-15 countries

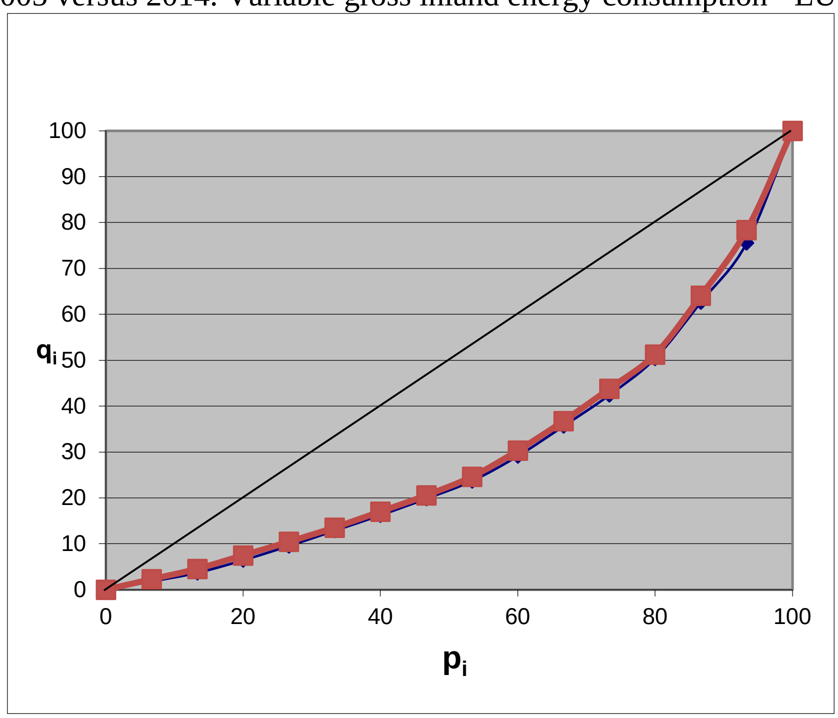
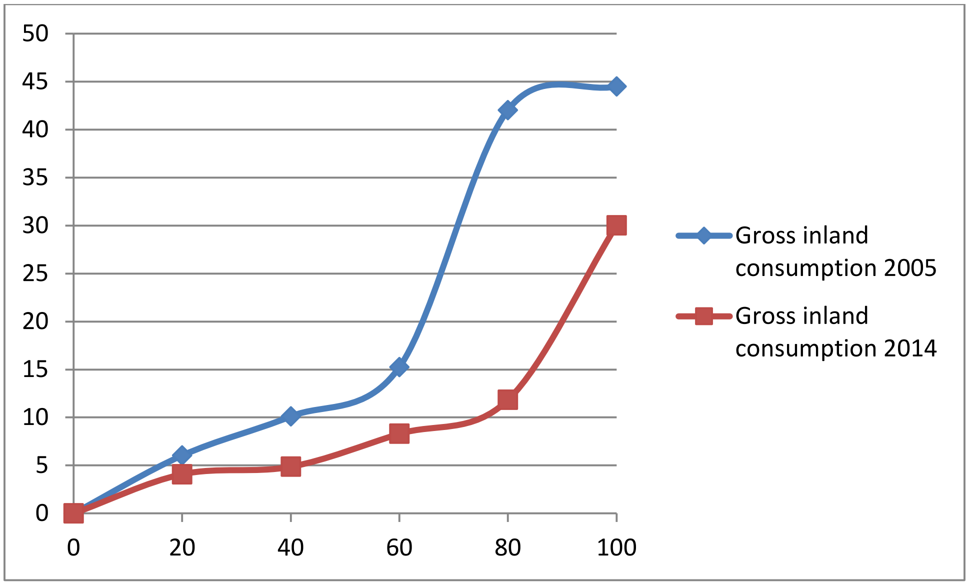


Figure 2:

Pen’s Parade (Quantile Function) for Gross inland energy per capita consumption, EU15 countries, 2005 and 2014



Note: On the horizontal axis, each country is ranked from poorest to richest and the vertical axis shows the level of EC per capita.

Table 1:
Gross inland consumption per capita (thousands) and population (millions) by quintile. EU-15

Gross inland consumption per capita	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Lowest (P20)	5,23	5,08	4,84	4,72	4,43	4,53	4,25	4,34	4,31	4,08
Low-mid (P40)	6,04	5,94	5,89	5,74	5,50	5,36	5,13	5,02	5,03	4,87
Middle (P60)	10,11	9,93	9,78	9,88	9,43	9,79	9,24	9,05	8,82	8,30
Mid-upper (P80)	15,24	15,17	15,14	14,69	13,52	13,50	13,09	12,94	12,21	11,83
P80/P20	2,91	2,98	3,13	3,11	3,05	2,98	3,08	2,99	2,83	2,90
Population	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Lowest (P20)	5,39	5,40	5,43	5,46	5,49	5,51	5,53	5,56	5,58	5,62
Low-mid (P40)	9,90	9,95	9,**99**	10,02	10,06	10,10	10,11	10,12	10,12	10,12
Middle (P60)	13,18	13,22	13,25	13,29	13,32	13,34	13,35	13,38	13,44	13,52
Mid-upper (P80)	58,80	59,15	59,60	60,06	60,44	60,77	60,99	61,30	61,59	61,37
P80/P20	10,92	10,95	10,98	11,01	11,02	11,03	11,02	11,03	11,04	10,92

Source: Authors' elaboration.

Table 2:
Inequality measures

Inequality measures	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Gini	0,4427	0,4519	0,4505	0.4445	0,4437	0,4445	0.4384	0.4324	0,4321	0,4216
$GE(0)$	0,2812	0,2924	0,2902	0,2831	0,2822	0,2823	0,2735	0,2656	0,2651	0,2510
$GE(1)$	0,2948	0,3127	0,3080	0,2969	0,2965	0,2986	0,2871	0,2776	0,2779	0,2628
GE (2)	0,3766	0,4110	0,3999	0,3771	0,3776	0,3824	0,3604	0,3435	0,3447	0,3211
$A_{0.5}$	0,1356	0,1420	0,1405	0,1366	0,1363	0,1368	0,1324	0,1286	0,1285	0,1220
A_1	0,2451	0,2535	0,2519	0,2466	0,2459	0,2460	0,2393	0,2333	0,2329	0,2219
$A_{1.5}$	0,3297	0,3372	0,3359	0,3306	0,3296	0,3286	0,3210	0,3139	0,3128	0,2992
A_2	0,3940	0,3992	0,3981	0,3933	0,3923	0,3897	0,3817	0,3742	0,3725	0,3571

Source: Authors' elaboration.

All the inequality measures considered (Gini index, Generalized Entropy measures and Atkinson indices) agree that inequality is lowest in 2014 and it is highest in 2006 (see Table 2). So, the choice of one measure over another is not a key point in the discussion of *EC* distribution. As the EU-15 countries are extremely heterogeneous in some aspects, four clusters of countries are generally considered: Mediterranean border (Spain, Italy, Portugal and Greece), Continental (Germany, France, Belgium, Luxembourg and Austria), Nordic (Denmark, Finland, Sweden and the Netherlands) and Anglo-Saxon ones (United Kingdom and Ireland).

The results of these decompositions are included in Table 3. As can be noticed, the "within inequality" is very small in all the groups of countries and the “between-group” component of inequality explains the highest share of total inequality. As pointed out by Cowell (2005), Theil's approach to the measurement of inequality is set in the context of subsequent developments over recent decades. It leads naturally to a very general class of decomposable inequality measures which are closely related to other ones.

Thus, once we have decomposed changes in the inequality groups (between and within-group components) and countries have been grouped according to a regionalization criteria, we want to point out the following results. Firtly, inter-group inequality, and its decline, can explain the reductions that occurred in international inequalities. Secondly, with regard to the "between" component the main reduction is noticiable when we compare 2005 and 2014. Thirdly, we have to take into account the relative population of each group. The results suggest that althoug *EC* per capita typically explains international inequalities, there exist differences by groups of countries.

Table 3:
Decomposition of Inequality in EC per Capita by clusters of countries, 2005-2014 using the Generalized Entropy Indices

Inequality measures	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
GE (0) - All EU15	0,2812	0,2924	0,2902	0,2831	0,2822	0,2823	0,2735	0,2656	0,2651	0,2510
GE(0) Continental	0,1805	0,1975	0,1891	0,1810	0,1870	0,1813	0,1674	0,1577	0,1623	0,1503
GE(0) Mediterranean	0,0272	0,0200	0,0171	0,0167	0,0167	0,0122	0,0102	0,0122	0,0120	0,0085
GE(0) Nordic	0,0355	0,0337	0,0333	0,0338	0,0321	0,0432	0,0410	0,0376	0,0521	0,0454
GE(0) Anglo-saxon	0,0027	0,0004	0,0008	0,0001	0,0006	0,0000	0,0000	0,0002	0,0003	0,0001
Decomposition	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Within inequality	0,0773	0,0802	0,0766	0,0738	0,0754	0,0752	0,0694	0,0659	0,0712	0,0645
Between inequality	0,2040	0,2122	0,2136	0,2093	0,2068	0,2071	0,2041	0,1998	0,1939	0,1865
GE (1) - All EU15	0,2948	0,3127	0,3080	0,2969	0,2965	0,2986	0,2871	0,2776	0,2779	0,2628
GE(1) Continental	0,0071	0,0763	0,0710	0,0651	0,0677	0,0724	0,0629	0,0563	0,0604	0,0525
GE(1) Mediterranean	0,0270	0,0199	0,0170	0,0165	0,0166	0,0121	0,0101	0,0121	0,0119	0,0085
GE(1) Nordic	0,0321	0,0307	0,0304	0,0309	0,0292	0,0383	0,0366	0,0335	0,0452	0,0399
GE(1) Anglosaxon	0,0027	0,0004	0,0008	0,0001	0,0006	0,0000	0,0000	0,0002	0,0003	0,0001
Decomposition	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Within inequality	0,0141	0,0550	0,0515	0,0477	0,0489	0,0532	0,0468	0,0423	0,0472	0,0407
Between inequality	0,2807	0,2577	0,2566	0,2492	0,2477	0,2454	0,2402	0,2353	0,2308	0,2221

Source: Authors' elaboration.
Note: *GE* denotes the corresponding Generalized Entropy Index when α=0 or α=1.

4. Conclusions

Reducing gross inland energy consumption, especially non-renewal energies, is one of the central objectives of EU countries. In this paper, we have combined methodological issues based on the standard tools in the measurement of income inequality and empirical aspects. Although these techniques have been applied to energy economics (Groot, 2010), specially to the inequality measurement of carbon emissions, as far as we know, this is the first time it has been applied to gross inland energy consumption in the EU-15 countries with the most recent data (2005-2014). Other authors, as Rosas-Flores et al. (2010), have pointed out that the search for equity in energy consumption is one of the main objectives of the millennium. In this sense, it is not only just to talk about inequality, but also to demonstrate objectively its existence. The measurement of inequalities between countries and within a country is the first step before taking decisions and actions put in place strategies in order to reduce and eventually eliminate these inequalities. Transforming the results of these studies into policies is a challenge to be faced.

The analysis presented above yielded the following interesting results. Small shifts in the Lorenz curves are visible; and inequality decreased over the period. However, there are important differences not only by clusters of countries (Mediterranean, Continental, Nordic and Anglo-Saxon) but also at the bottom of the distribution. In this sense, the within group inequality is really small. The use of the Theil index has allowed us to analyze the evolution of international inequality in EC and has provided helpful information for the debate on inequalities related to energy consumption in the EU countries. As can be noticed from the small shift of the Lorenz curve, the inequality in the distribution of *EC* across countries has decreased from 44.27% to 42.16% along the period. However, these differences are clearer when we base our results on the Parade approach. In this sense, it is important to point out that although inequality decreased over the period 2005-2014, *EC* was much higher at the bottom of the distribution in 2005 than in 2014 and the value of the Gini coefficient for *EC* distribution varies from 0,4427 in 2005 to 0,4519 in 2006 and decreased since 2010. This is an important result which is supposed to have consequences on climate change. The EU-15 *EC* has fallen over the last years although as we have pointed out in this paper there exist huge differences among countries.

Finally, it is important to notice that the previous analysis produced concerning the study of international inequalities in EC per capita is relevant for the study of world inequality in itself (between countries). However, and as described by Duro (2013), worldwide inequality can be broken down into a component that reflects differences in average *EC* between countries and a second element that registers inequalities between people within each group of countries.

As recommendations for policymakers we can add the followings: reduce energy consumption in all the EU-15 countries, especially non-renewal ones, investment in renewal energies, adoption of new technologies more energy-performing and increase energy efficiency.

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