Measuring sustainable economic development through a multidimensional Gini index

Misurare lo sviluppo economico sostenibile con l'indice multidimensionale del Gini

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Abstract This paper analyses the evolution of sustainable economic development inequality in Italy as regards the efforts made by each administrative Region, as a response to the main EU policies issued by the environmental and energy sector. For this purpose a multidimensional generalization of the Gini index has been performed, taking into account two different dimensions (energy and environment), in a time frame of six years (2008-2013). The multidimensional Gini results confirm the positive effect recorded by certain EU policies in determining a reduction in the inequality levels among the Italian Regions. A counterfactual analysis further underlined the relevant role played by the energetic dimension against the environmental one in strengthening Regional performances.

Abstract *Questo contributo analizza l'evoluzione dello sviluppo economico sostenibile in Italia per valutare gli sforzi fatti dalle regioni italiane alla luce delle politiche attuate dall'Unione Europea nel settore energetico e ambientale. A questo scopo, è stato calcolato l'indice multidimensionale del Gini prendendo in considerazione due dimensioni (energia e ambiente), nel periodo di sei anni (2008-2013). I risultati dell'indice Multidimensionale del Gini confermano gli effetti positivi registrati dalle politiche europee nel determinare una riduzione dei livelli di disuguaglianza tra le regioni italiane. L'analisi controfattuale sottolinea ulteriormente il ruolo cruciale giocato dalla dimensione energetica rispetto a quella ambientale nel rafforzare le performance regionali.*

Key words: sustainable economic development, Multidimensional Gini Index, EU policy, energy and environment

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1 Introduction

The Europe 2020 Strategy, adopted in 2010 by the European Council includes an ambitious economic strategy aimed at supporting Member States in converging towards smart and inclusive growth. For this purpose, a series of environmental, energetic and social targets, to be achieved by 2020, have been set. These political inputs have affected the distribution of sustainable economic development patterns among EU regions. While sustainable development is intended to encompass the three pillars of economic development, social equity and environmental protection, over the past 20 years it has often been compartmentalized as an environmental issue (IISD, 2010). The well-being of future generations compared to ours will depend on what resources we pass on to them, in which sustainable growth approach is intended as a "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCDE, 1987). In this approach, energy is central to improved social and economic well-being, being indispensable to most industrial and commercial wealth generations. Achieving *sustainable economic development* on a global scale will require the judicious use of resources, technology, appropriate economic incentives and strategic policy planning at local and national levels. For this purpose and considering that the reduction of unequal distribution of opportunities increases the general well being of a Region, therefore becoming very relevant in ensuring distributive justice and measuring it. The present work aims to assess the economic sustainable development at Italian regional level, by performing a multidimensional Gini index following the normative approach to inequality measurement. In the normative approach an inequality index make use of a social evaluation function able to combine the information on inequality for the different dimensions and, incorporating the correlation between them, allowing for the non substitutability of indicators/dimensions. The Gini coefficient is probably the best known and most used inequality index in economics and in multidimensional cases, with an intrinsic attractiveness, due to its interpretation in terms of the underlying rank-dependent social evaluation function (a function allowing it to attach welfare weights to individuals depending on their position in the total distribution).

2 Method and analysis

In this paper to evaluate sustainable economic development from a social welfare perspective we make a composite index based on the recent contribution of Decancq and Lugo (2012). Following the normative approach to inequality measurement, the authors propose the following two inequality indices based on Gini coefficient able to measure inequality of well-being:

$$I^2(X) = 1 - \frac{\sum_{i=1}^{n}\left[\left(\frac{r_i}{n}\right)^{\delta} - \left(\frac{r_i - 1}{n}\right)^{\delta}\right]\left(\sum_{j=1}^{m} w_j \mu(x_j)^{\beta}\right)^{1/\beta}}{\left(\sum_{j=1}^{m} w_j \mu(x_j)^{\beta}\right)^{1/\beta}} \quad (1)$$

$$I^1(X) = 1 - \frac{\left[\sum_{j=1}^{m} w_j \left(\sum_{i=1}^{n}\left[\left(\frac{r_j^i}{n}\right)^{\delta} - \left(\frac{r_j^i - 1}{n}\right)^{\delta}\right] x_j^i\right)^{\beta}\right]^{1/\beta}}{\left(\sum_{j=1}^{m} w_j \mu(x_j)^{\beta}\right)^{1/\beta}} \quad (2)$$

The multidimensional social evaluation function used in these formulations is derived in two steps combining two distinct aggregations: one aggregation across dimensions and one across individuals (see Decancq and Lugo (2012) for details).
With the vector $\boldsymbol{w} = (w_1, w_2, \dots, w_m) \in \mathbb{R}^n$ and $\sum_{j=1}^{m} w_j = 1$ and $w_j > 0$;
the β parameter is related to the elasticity of substitution between the dimensions, when $\beta = 1$ the dimensions of well-being are seen as perfect substitutes. As $\beta \rightarrow -\infty$ the dimensions tend to perfect complementarity (Decancq & Lugo, 2012, p. 728).
r_i is the rank of unit *i* on the basis of vector $s^i = \left(\sum_{i=1}^{m} w_j (x_j^i)^{\beta}\right)^{1/\beta}$;
$\mu(x_j)$ is the dimension-wise mean and the δ>0 parameter is related to inequality aversion. The level of aversion to inequality identifies the two principal cases of social welfare function: the utilitarian and the Rawlsian social welfare function. The first is an unweighted sum of individual outcomes while the second one identifies social welfare with the welfare of the least performing units in the outcome distribution. In the utilitarian case the inequality aversion is zero. We consider a δ=2 that defines the Gini social evaluation function and $w_j = 1/m$.
Considering two relevant dimensions of environmental sustainability wellbeing (e.g. environment and energy) for the 20 (n) Italian regions, each distribution matrix X in $\mathbb{R}_{++}^{20\times 2}$ (with $\mathbb{R}_{++}^{n\times m}$ indicating a set of positive real numbers) represents a distribution of the outcomes for the 20 regions in the 2 dimensions. An element of the distribution matrix x_j^i denotes the outcome of region i in dimension j. A row of matrix X refers to the outcomes of one region, and a column refers to the outcome in one dimension. As our study considers two specific dimensions (environment and energy), not complementary with each other, we assume particular importance in the correlation among the ranks of the elementary indicators, in order to evaluate sustainable economic development inequality among the Italian Regions. According to this assumption, a Region with a good position in all the elementary indicators, thus with a higher correlation among ranks, will experiment a better wellbeing status. To choose beta value in (1) and (2) we consider a graphical method. For each index we create two graphs: in the first we plot index's values and in the other the logarithm of the indexes, both for the different β value (-2: -3; 1; 2). We choose $\beta = -2$ where the index and their logarithm show a very small increase in value. This choice is done separately from positive and negative values of beta because both of the indices vary considerably passing from positive to negative

ones. Table 1 shows indicators used for the analysis. From the initial 9 indicators only six have been considered due to the presence of high correlation between some of them. There are four indicators considered for the energy dimension, and two for the environmental one. The selected indicators are inspired by those suggested by the International Atomic Energy Agency (IAEA, 2005) and by the political framework of the EU 2020 Strategy, as regards the energetic and climate change targets (Eurostat). The decision to consider a time period of six-years is due to the objectives set in the EU2020 Strategy, above all as regards the renewable energy targets, which are mainly based on the entry coming into force in the second Directive 2009/28/EC in the field of renewable.

Starting from the raw data, variable with negative (Dfct/Srpls) or zero (HighVol) values are translated to $x' = (x - minimum) + 0.1$, so to assume positive real values, a normalized matrix has been built, by dividing each entry to the dimension-wise mean, to eliminate the influence of different measurements scale. In the considered period about 50% of Italian regions are in deficit of production with very different patterns observed at territorial level. The islands and southern regions are in surplus of production (+1979 in southern regions; +1273 in the islands) and the northern regions are in deficit (northwest -4903) even if southern and island regions are those with the lowest percentage of renewable energy production (data not showed).

Table 1: Elementary indicators used in the construction of the Multidimensional Gini index

Indicator (time period: from 2008 to 2013)	**Acronym**	**Unit of measure**	**Mean**	**Min**	**Max**
ENERGY DIMENSION					
Deficit/Surplus per head: difference between total energy production and total energy consumption	Dfct/Srpls	Gwh	-2167.72	-26446.40	17572.00
High Voltage grid (380) per 100 inhabitant	HighVol	Km/pop	0.02	0.00	0.10
Renewable production per head	Renew	Gwh/pop	0.36	0.03	1.01
Domestic energy consumption per head	Domestic_ Cons	Gwh/pop	1135.56	875.00	1581.00
ENVIROMENTAL DIMENSION					
Sale GPL per 100 Total vehicle	Sale_GPL	1000 tonnes	2.37	0.16	7.41
Car-bike park > EURO 3	Euro 3	%	43.09	19.05	79.66

Source: Author's elaborations on dataset: Terna – "Dati statistici sull'energia elettrica in Italia"; Annuario Statistico dell'Automobile Club d'Italia (ACI). Time period considered: 2008 to 2013.

The high voltage grid per 100 inhabitant (HighVol per 100 inhabitant), the production of renewable energy (Renew) and sale of GPL car per 100 vehicles also shows a very high variation in the considered period.

As our study considers two specific dimensions (environment and energy), not complementary with each other, we assume particular importance to the correlation among the ranks of the elementary indicators in order to evaluate the *sustainable economic development inequality* among the Italian Regions. According to this assumption, a Region with a good position in all the elementary indicators, thus with a higher correlation among ranks, will experiment a better wellbeing status. For this reason the I^2 index is preferred and in particular those results that consider $\beta = -2$, indicating the non-substitutability of indicators. Moreover, to simplify the analysis, we consider the same weight equal to $1/m$ for all dimensions.

3 Results and conclusions

Results obtained from $I^1$and I^2 indices are reported in Figure 1. The I^2 denotes a relevant decrease in the *sustainable economic development* inequality over the years. In particular, the major degree in the inequality reduction correspond to the issue of the second important EU Directive on RES (Directive 2009/28/EC) that, at EU level, set mandatory targets in terms of energy renewable productions, (Giacomarra & Bono, 2015; Bono & Giacomarra, 2016). The validity of the I^2 is further confirmed by the results achieved by the I^1 that, show both a lower inequality level and no relevant changes during years. A situation far from the effective reality of the Italian Regions that, has, experimented particular progress since the year 2008. Differently from the I^2, the I^1 (independently from the values assumed by β) principally shows an inequality level more similar in the time and for different values of beta.

Figure 1. Comparison between I^1 and I^2

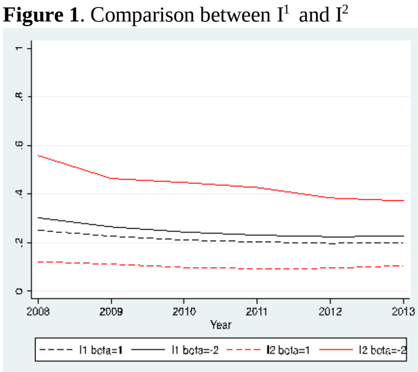
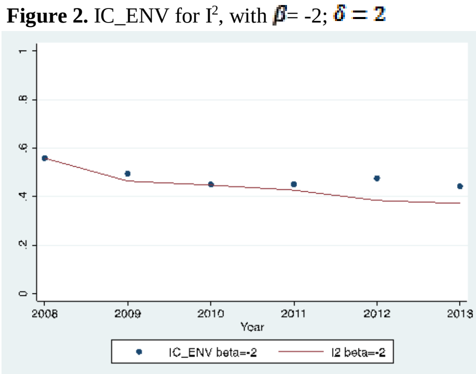


Figure 2. IC_ENV for I^2, with β= -2; $\delta = 2$



***Source**: Author's elaborations using Stata 13*

Having identified the $\mathbf{I^2}$ with negative β values as the best index to analyse the evolution of the *sustainable economic inequality* in Italy, it is interesting to apply two counterfactual analyses. In order to carry out the counterfactual analysis, for the first attempt we have only considered the trend recorded by the environmental dimension (IC_ENV).. In doing so, we have left the energetic dimension values and their ranking fixed at the value recorded in 2008 (in other words, not considering its trend). While, for the counterfactual analysis performed on the energetic dimension (IC_ENER), we have only considered the environmental values for the year 2008, considering the trend of the energetic dimension.To compute the IC_ENV (the only one reported here), the $\mathbf{I^2}$ has been calculated keeping both the energetic indicators and their ranking correlations at the initial year, 2008, while considering the change in levels of the environmental indicators. Figure 2 shows the results and the points represent the values of I^2 (IC_ENV). As shown by Fig. 2, without the energetic component, the overall *sustainable economic development* in Italy would have recorded a higher level of inequality among Regions (> 0.4), for the years 2012 and 2013. Concluding, in Italy, during 2008-2013, regions recorded a reduction in *sustainable economic development inequality*. After a positive effect belonging to policies implemented in both the energetic and environmental sectors, in the last two years energetic policy achieved more diffused and capillary positive effects than those in the environmental one. This is true, if we consider that in the energetic sector, the EU commitments thanks to its Directives, financial tools and incentives, have been sharper, practical and continuous in time, producing a clear and credible framework. For what in our knowledge, this work represents the first attempt to propose a Multidimensional Gini Index applied to the *sustainable economic development inequality* field and, above all, taking into account the inequality level among Regions and no physical individuals. The index's ability to capture the rankings between dimensions is an important feature for new policies and monitoring tools. This work presents some limitations that should be taken into account in future research: firstly, it would be interesting to make a comparison among different EU Regions (NUT 2), a difficult challenge due to the unavailability of detailed and affordable comparable indicators in other EU Regions. Secondly, a wider number of dimensions and indicators could be inserted in the multidimensional Gini Index, in order to include a more complete analysis of the complex *sustainable economic development inequality* phenomenon.

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