

Policy Impacts on Inequality

Inequality and Axioms for its Measurement





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by

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1. SUMMARY

This tool illustrates the concept of desirable properties any inequality index should respect. In particular, it introduces the distinction between a positive and a normative approach to inequality analysis. Then, it discusses the role of axioms in inequality measurement and their conceptual meaning. Finally, using the Gini Index and the variance, a step-by-step procedure and numerical examples are introduced for operational purposes.

2. INTRODUCTION

Objectives

The objective of the tool is to introduce to the use of simple and complex inequality measures to compare income distributions, on the basis of some desirable properties such indexes should respect.

This module provides the tools to choose among alternative inequality measures for operational purposes, as evaluating the effects of public programmes on the distribution of income.

This tool also deals with some approaches of measuring income inequality. It will show how information on any given income distribution may be conveyed by indexes conforming to some desirable properties (axioms).

Target audience

This module targets current or future policy analysts who want to increase their capacities in analysing impacts of development policies on inequality by means of income distribution analysis. On these grounds, economists and practitioners working in public administrations, in NGOs, professional organisations or consulting firms will find this helpful reference material.

Required background

Users should be familiar with basic notions of mathematics and statistics.

Links to relevant EASYPol modules, further readings and references are included both in the footnotes and in section 6 of this module¹.

¹ EASYPol hyperlinks are shown in blue, as follows:

- a) training paths are shown in **underlined bold font**;
- b) other EASYPol modules or complementary EASYPol materials are in ***bold underlined italics***;
- c) links to the glossary are in **bold**; and
- d) external links are in *italics*.

3. CONCEPTUAL BACKGROUND

3.1. General issues

Inequality is not a self-defining concept, as its definition may depend on economic interpretations as well as ideological and intellectual positions. If we compare total income to a cake, inequality can be thought of as deriving from *the way that a cake is divided among individuals*. In this sense, inequality is the way *an actual income distribution deviates from a «benchmark» for income distribution*.

Economic attitudes, as well as ideological and intellectual positions, may cause differing views about the size of inequality, its relevance and policies that might be implemented to deal with it. Furthermore, income inequality might be seen as a part of a more general concept of «economic inequality», even though «income conditions» are often a good proxy for «economic conditions», because income shapes people's living standards and it is generally highly correlated with other well-being indicators.

Nevertheless, we should be aware of the limitations of this approach, as total income is certainly an important factor in shaping economic inequality but it might not be the only one. Income inequality mainly focuses on a concept of **inequality of outcomes**. An alternative, or rather complementary, view is to focus on **inequality of opportunities**. There is a relation between the two concepts, as inequality of outcomes may well derive from inequality of opportunities. For example, if a talented individual cannot afford to go to university because he/she is poor (inequality of opportunities), he/she is likely to have a lower income level (inequality of outcomes) in his/her life cycle.

3.2. The descriptive and normative approach to inequality

The aim of this tool is to concentrate on **income inequality** and on how to measure it. In general, there are two main approaches to treat the issue of income inequality:

- descriptive
- normative

In the **descriptive approach**, value judgements about the nature of inequality (bad or good) are not explicit. Technically speaking, no [Social Welfare Function \(SWF\)](#) has yet been specified². We can simply assume ourselves to be impartial observers, trying to understand income inequality as a **deviation from a given benchmark**. For simplicity, we can contrast income inequality with **income equality**. In this way, the benchmark might be an income distribution with all equal incomes. The main characteristics of the descriptive approach are:

- a. In the **descriptive approach**, the analyst takes a picture of inequality as it is in state A and describes changes in income distribution under different scenarios, for instance, state B, but he/she does not dispose of devices to state whether A is better than B or vice versa. For example, if in state A, 5 per cent of total

² See the EASYPol Module 041: [Social Welfare Analysis of Income Distribution: Social Welfare, Social Welfare Functions and Inequality Aversion](#)

income is in the first decile and 10 per cent in the second decile, while in state B, 7 per cent of total income is in the first decile and 8 per cent in the second decile, is A better than B?

Descriptive indexes are usually mathematical formulas. As such, they have mathematical properties. Mathematical properties drive the way the index behaves when an income distribution changes from state A to state B. In other words, mathematical properties drive the mechanics of the inequality index. Perhaps, we would also like those same indexes to reflect individual feelings on the measurement of income inequality. Individual feelings drive the way the inequality index should behave according to our judgement. The way the index actually behaves because of its mathematical properties and the way we would like it to behave according to our judgement, may not necessarily be the same.

- b. Descriptive inequality indexes are many. How are we to choose among them? We can get help by specifying [axioms](#). For example, if our feeling is that income inequality would be lower if richer people transfer income to poorer people, we should choose an index with this mathematical property, excluding all indexes that have mathematical properties at odds with this personal feeling.
- c. Different inequality indexes have different mathematical properties, and not every index may reflect our personal feeling. Therefore, it might well be the case to have different indexes giving conflicting answers on inequality changes from state A to state B. This is a very important issue that requires a careful understanding of the inequality index used.

The **normative approach** enables the analyst to compare income distributions in terms of «greater or lesser desirability», according to a priori value judgement. In other words, this approach implies specifying if inequality is bad or good, how much is bad or good, how much society gains or loses from it, and how to compare individual incomes. To this extent, the normative approach requires specifying the SWF.³

In the normative approach, the specification of a SWF qualifies the inequality measure. In other words, the inequality index to be used is driven by the way the SWF is specified. As in the case of the descriptive approach, there might be desirable properties (axioms) that an SWF could satisfy.⁴

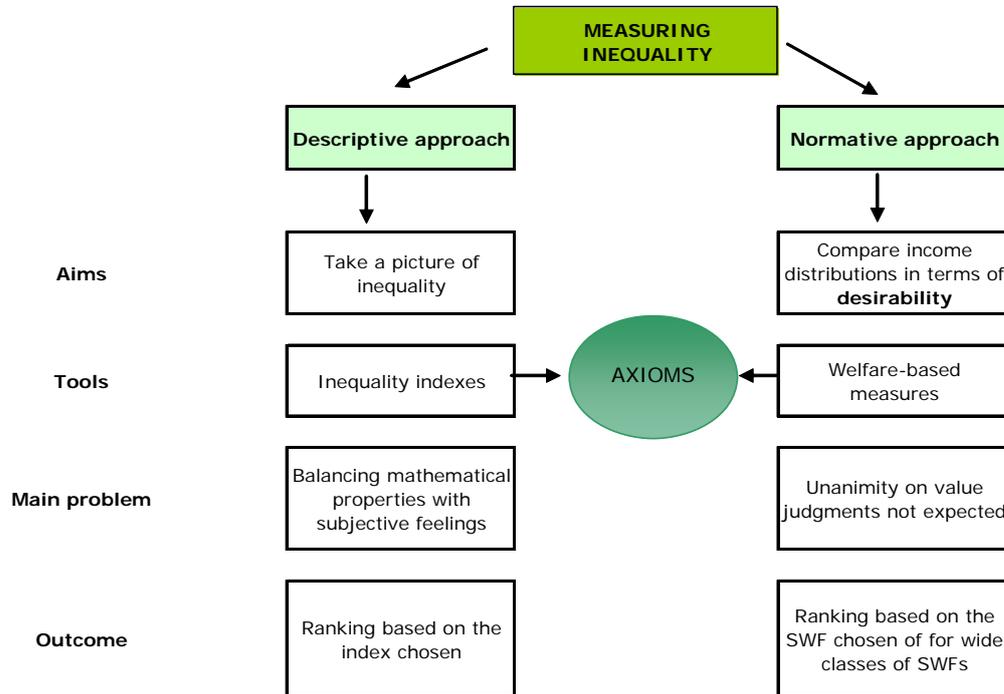
The main problem of using a normative approach is that there might be as many SWFs as there are people in a society, reflecting subjective judgements. Income inequality might therefore appear more or less severe depending on the SWF chosen.

Figure 1 makes a synthesis of the basic features of the approaches to inequality measurement, distinguishing aims, tools, problems and outcomes.

³ See Champernowne and Cowell (1998).

⁴ As a consequence, a SWF may be either fully cardinalised (i.e. a functional form may be fully specified, giving complete ranking) or imposed a set of minimum requirements (giving a partial ranking).

Figure 1: How to measure inequality



3.3. The role of axioms in inequality measurement

Axioms, in inequality measurement, are desirable properties of inequality measures. They define the way in which inequality measures should behave.

Using axioms may help to choose among inequality indexes. When an inequality index is chosen because it respects some desirable properties, it is said that inequality measurement follows an **axiomatic approach**.

Five main axioms will be considered:

- the principle of transfers (also known as the Pigou-Dalton principle)
- scale invariance
- translation invariance
- the principle of population
- decomposability

We can anticipate that if an inequality index satisfies the principle of transfers, scale invariance and the principle of population at the same time, it belongs to the class of **relative inequality indexes (RII)**.

A very useful property of the RII class is that they rank inequality in the same way as the **Lorenz Curve** ordering.⁵ If the Lorenz Curve of the distribution **y** **dominates** the Lorenz Curve of a distribution **x** over the relevant range, indicating less Lorenz inequality in **y**, all **RII** indexes would give the same ranking. **Lorenz dominance** is therefore a *sufficient* condition for **RII** (there is an *ordinal equivalence* between the two rankings). If Lorenz dominance fails, there might be **RII** ranking the two distributions differently.⁶

However, the basic difference between the Lorenz criterion and RII is that the Lorenz Curve gives a *partial ordering*, as the Lorenz criterion is silent when Lorenz Curves intersect, while RII may give a *complete ordering* as they reduce income distributions to a single number

3.3.1. The Pigou-Dalton principle of transfers (PT)

This axiom requires the inequality measure to change when income transfers occur among individuals in the income distribution. In particular:

- Inequality indexes should fall with a **progressive transfer**, i.e. an income transfer from richer to poorer individuals;
- Inequality indexes should rise with a **regressive transfer**, i.e. an income transfer from poorer to richer individuals.

To illustrate the behaviour of the inequality index, let us define a generic inequality index **I**. Let us also assume an income distribution:

$$\mathbf{y} = (y_1, y_2, \dots, y_i, \dots, y_k, \dots, y_n).$$

Let us now assume that a *progressive transfer* δ occurs from income y_k to y_i , where $y_k > y_i$. A new income distribution yields the following result:

$$\mathbf{y}^* = (y_1, y_2, \dots, y_i + \delta, \dots, y_k - \delta, \dots, y_n)$$

with $y_k - \delta > y_i + \delta$, i.e. the transfer does not reverse the relative position of the two individuals. Now, an inequality index satisfies *PT* if $\mathbf{I}(\mathbf{y}^*) < \mathbf{I}(\mathbf{y})$, i.e. if it gives a lower value for \mathbf{y}^* than for the initial \mathbf{y} .

It is sometimes useful to distinguish between two versions of the principle of transfers:

- **Weak principle of transfers (WPT)**

⁵ See Foster (1985).

⁶ This makes Lorenz dominance a useful index for inequality comparisons in a descriptive sense, as whenever it occurs, there is no need to calculate the value of any RII to know in which income distribution inequality is lower.

- **Strong principle of transfers (SPT)**

WPT simply requires the inequality index to change when an income transfer occurs. In this sense, it conforms to the general definition so far discussed.

SPT requires a little more, in particular that the amount of the change in inequality due to an income transfers be dependent only on the *distance* between individual ranks, independently of their location in the income distribution.

3.3.2. Scale invariance (SI)

Scale invariance requires the inequality index to be invariant to equi-proportional changes of the original incomes. For example, starting from \mathbf{y} , we could obtain a new distribution multiplying all incomes by λ . The new distribution, in this case, would be:

$$\mathbf{y}^* = (\lambda y_1, \lambda y_2, \dots, \lambda y_i, \dots, \lambda y_k, \dots, \lambda y_n)$$

An inequality index is scale invariant if $\mathbf{I}(\mathbf{y}) = \mathbf{I}(\mathbf{y}^*)$, i.e. if the index does not change when all income are scaled by the same factor. Scale invariance means that income changes are distributionally neutral only if they occur in the **same proportion** for all individuals in the income distribution.

3.3.3. Translation invariance (TI)

Translation invariance requires the inequality index to be invariant to uniform additions or subtractions to original incomes. For example, starting again from \mathbf{y} , we could obtain a new income distribution adding θ to all incomes. The new distribution, in this case, would be:

$$\mathbf{y}^* = (y_1 + \theta, y_2 + \theta, \dots, y_i + \theta, \dots, y_k + \theta, \dots, y_n + \theta)$$

Therefore, an inequality index is translation invariant if $\mathbf{I}(\mathbf{y}) = \mathbf{I}(\mathbf{y}^*)$.

Translation invariance means that income changes are distributionally neutral only if they occur in the **same absolute amounts** for all individuals in the income distribution.

3.3.4. The principle of population (P)

The principle of population axiom requires the inequality index to be invariant to replications of the original population. Given an initial income distribution \mathbf{y} , replicating the population would give:

$$\mathbf{y}^* = (y_1, y_1, y_2, y_2, \dots, y_i, y_i, \dots, y_k, y_k, \dots, y_n, y_n)$$

where all incomes are replicated once. An inequality index satisfies the population principle if $\mathbf{I}(\mathbf{y}) = \mathbf{I}(\mathbf{y}^*)$.

3.3.5. Decomposability (D)

A very important axiom for inequality measurement is decomposability. So far, we have investigated inequality as «overall inequality» of a given income distribution. However, inequality may occur among different elements of income distribution (e.g., earned income or income from capital) or among different groups or sectors of population (e.g. workers, pensioners, agricultural workers, manufacturing workers, etc.)⁷

In any case, the decomposability axiom requires a consistent relation between overall inequality and its parts. If the original income distribution \mathbf{y} is composed by, say, n groups, and has an overall inequality $I(\mathbf{y})$ it must be that:

$$I(\mathbf{y}) = I(y)_1 + I(y)_2 + \dots + I(y)_n$$

i.e., total inequality must be equal to the sum of the various group inequalities.

4. A NUMERICAL EXAMPLE FOR AXIOMS

At this stage, it is worth giving a numerical example of how axioms work. However, as the analysis of the inequality indexes could not be yet addressed, examples will be built using the simplest index of dispersion, the **variance**⁸.

The variance measures the dispersion of a distribution around the mean, but since the differences from the mean are squared, it gives more weight to those values further away from the mean itself. In general, the higher the variance, the higher the variability in income distribution.

Let's state the formula of the variance:

$$V = \frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n}$$

For the purpose of the analysis, let's also define a relative variance index ($V(r)$), as the ratio between the variance and the maximum variance of the income distribution (V_{\max}), i.e. the variance that could be generated by an income distribution where total income is concentrated in the hands of only one individual:

$$V(r) = \frac{V}{V_{\max}}$$

⁷ See EASYPol Module 053: [Policy Impacts on Inequality: Decomposition of Inequality by Groups and Income Source](#).

⁸ See EASYPol Module 080: [Policy Impacts on Inequality : Simple Inequality Measures](#), and the most popular measure of inequality, EASYPol Module 040: [Inequality Analysis: The Gini Index](#).

The formula used for the Gini Index, in this context, is based on the covariance formula:

$$G = \frac{2Cov(y, F(y))}{\bar{y}}$$

where y denotes incomes, $F(y)$ is the cumulative distribution function and \bar{y} is the average income level.

Table 1 illustrates the behaviour of these two indexes for all axioms considered.

Table 1: The behaviour of the variance and the Gini Index

Individual	Incomes	Principle of transfers	Scale invariance	Translation invariance	Principle of population
					1,000
					1,000
					2,000
					2,000
					3,000
1	1,000	1,100	1,200	1,500	3,000
2	2,000	2,000	2,400	2,500	4,000
3	3,000	3,000	3,600	3,500	4,000
4	4,000	4,000	4,800	4,500	5,000
5	5,000	4,900	6,000	5,500	5,000
Mean income	3,000	3,000	3,600	3,500	3,000
Total income	15,000	15,000	18,000	17,500	30,000
Variance	2,500,000	2,305,000	3,600,000	2,500,000	2,222,222
Max V	45,000,000	45,000,000	64,800,000	61,250,000	90,000,000
Relative variance	0.0556	0.0512	0.0556	0.0408	0.0247
Gini index	0.267	0.256	0.267	0.229	0.267

First of all, let's consider the original income distribution (reported under the heading «Incomes»). This is an income distribution of five incomes belonging to five individuals. The average income level is 3,000 currency units, while total income is 15,000 currency units. The relative variance of this original income distribution is 0.0556. The Gini Index is 0.267.

Now, let's investigate how the two indexes react to the **principle of transfers**. Let's assume that 100 currency units are redistributed from the richest to the poorest individual. This is illustrated in the third column («Principle of transfers») where the poorest individual now has 1,100 currency units, while the richest individual now has 4,900 currency units. Mean income and total income are obviously the same, as only a

transfer of income among individual has occurred. In this case, both the variance and the Gini Index decrease (0.0512 and 0.256, respectively). Therefore, both indexes satisfy the principle of transfers.

Let us now move to the **scale invariance** axiom. The fourth column is the result of increasing each income of the original income distribution by 20 per cent. Both mean income and total income are therefore increased by the same amount (3,600 and 18,000 currency units, respectively). As we can easily see, both the variance and the Gini Index have the same values as those assumed in the case of the original income distribution (0.0556 and 0.267, respectively). Therefore, both indexes satisfy the scale invariance axiom.

The situation is different with regard to the **translation invariance** axiom. The fifth column reports a new income distribution obtained from the original one by adding 500 currency units to all incomes. In this case, mean income also increases by 500 currency units (3,500), while total income increases by 500 currency units times the number of individuals (5). The new total income is indeed 17,500 currency units. In this case, both the variance and the Gini Index decrease (0.0408 and 0.229), which means that they **do not satisfy** the translation invariance axiom. Rather, they decrease after absolute income increases, while they increase after absolute income reductions.

Finally, let's consider the **principle of population**. The far right column reports a new income distribution which is an exact replication of the original one. There are ten individuals instead of five, with incomes that exactly replicate the original income distribution. Therefore, mean income is the same (3,000 currency units), while total income is twice as much (30,000 currency units). It is worth noting the different behaviour of the variance and the Gini Index. The relative variance decreases, signalling less inequality, while the Gini Index stays the same, signalling that inequality has not changed. Therefore, the Gini Index satisfies the principle of population, while the relative variance does not.

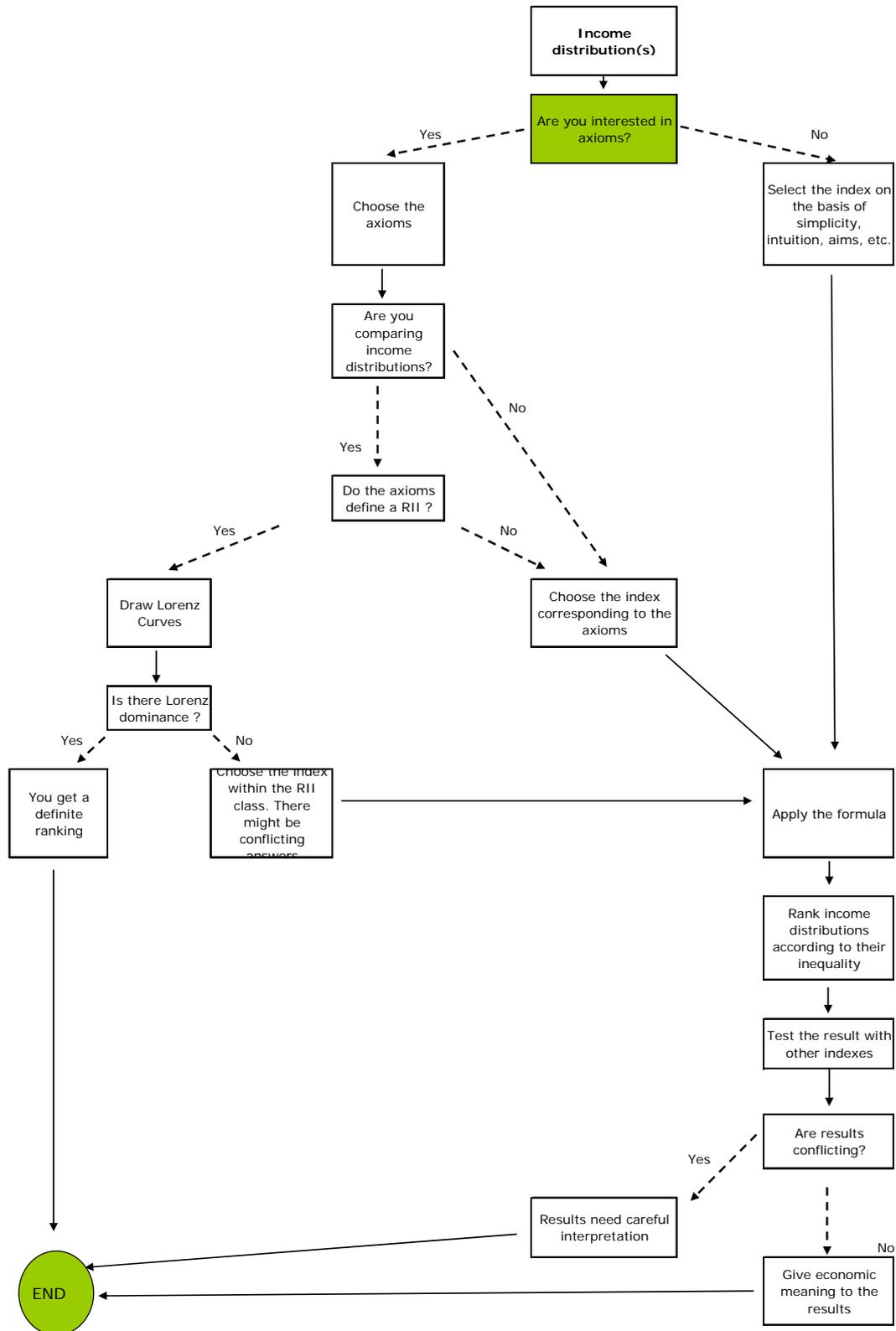
5. A GENERAL STEP-BY-STEP PROCEDURE TO SELECT INEQUALITY MEASURES

The conceptual background so far discussed and the discussion carried out in other modules⁹ allows us to define a sensible procedure to use inequality measures in order to get the maximum level of information on how to rank income distributions. This procedure can be summarised through a flow chart as in Figure 2:

⁹ See in particular, EASYPol Modules: 000 & 001 respectively: [Charting Income Inequality: The Lorenz Curve](#), and [Social Welfare Analysis of Income Distributions: Ranking Income Distributions with Lorenz Curves](#). Also, EASYPol Modules 040 & 041 respectively: [Inequality Analysis: The Gini Index](#); and [Social Welfare Analysis of Income Distributions: Social Welfare, Social Welfare Functions and Inequality Aversion](#); EASYPol Modules 050 & 051 respectively, [Policy Impacts on Inequality: Welfare Based Measures of Inequality](#) and [Policy Impacts on Inequality: The Theil Index and the other Entropy Class Inequality Indexes](#).

-
- **FIRST STEP: are we interested in using axioms?** If **yes**, the first step is to CHOOSE THE AXIOMS conforming to the aim of our analysis. If **no**, just select an index based on other features, as simplicity, intuition, convenience, available data, etc.
 - **SECOND STEP: if you chose yes at the first step, are we comparing income distributions?** If **yes**, then we have to solve the question in the third step. If **no**, select the index conforming to the chosen axioms.
 - **THIRD STEP: if you chose yes at the second step, do the axioms chosen define an RII?** If **yes**, we can exploit Lorenz Curves, plotting them for all income distributions; if **no**, we are back to the «no» of the previous question, i.e. choose the index conforming to the selected axioms.
 - **FOURTH STEP: after drawing Lorenz Curves, can we see Lorenz-domination?** If **yes**, the ranking obtained is robust to any inequality index belonging to **RII**. Descriptive inequality analysis can therefore stop here, by ranking distributions according to their position in the Lorenz diagram and giving economic meaning to the results. Any RII would rank those distributions in the same order (ordinal equivalence). If **no**, we must be prepared to choose an index within the **RII** class, having in mind that different indexes might give different answers.
 - **FIFTH STEP: if you chose no at the first step or at the second step or at the third step, then, after having selected a suitable index, simply apply the formula.**
 - **SIXTH STEP: see the results and rank income distributions from the lowest to the highest inequality.**
 - **SEVENTH STEP: as we are out of the logic of Lorenz domination, whatever the index used, it is important to test the results calculating other inequality indexes. After that simply check if there are conflicting results.**
 - **EIGHTH STEP: if you chose yes at the seventh step, results must be interpreted with caution, as they are measure-specific. Changing the measure can change the outcome. If you chose no, start to give an economic meaning to the results.**

Figure 2: A general step-by-step procedure to choose inequality indexes



6 READERS' NOTES

6.1. Time requirements

Time required to deliver this module is estimated at about three hours

6.2. EASYPol links

Selected EASYPol modules may be used to strengthen readers' background knowledge and to further expand their understanding on inequality and inequality measurement.

This module belongs to a set of modules that discuss how to compare on inequality grounds alternative income distributions generated by different policy options. It is part of the modules composing a training path addressing [Analysis and monitoring of socio-economic impacts of policies](#).

The following EASYPol modules form a set of materials logically preceding the current module, which can be used to strengthen the user's background:

- EASYPol Module 000: [Charting Income Inequality: The Lorenz Curve](#)
- EASYPol Module 001: [Ranking Income Distribution with Lorenz Curves](#)

Issues addressed in this module are further elaborated in the following modules:

- EASYPol Module 040: [Inequality Analysis: The Gini Index](#)
- EASYPol Module 051: [Policy Impacts on Inequality: The Theil Index and the other Entropy Class Inequality Indexes](#)
- EASYPol Module 041: [Social Welfare Analysis of Income Distributions: Social Welfare, Social Welfare Functions and Inequality-Aversion](#)
- EASYPol Module 050: [Policy Impacts on Inequality: Welfare Based Measures of Inequality](#)

6.3. Frequently asked questions

- ✓ How many methods are there to investigate economic inequality?
- ✓ How do we measure inequality?
- ✓ Should measurement of inequality obey some pre-defined properties?

7. REFERENCES AND FURTHER READING

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Module metadata

1. EASYPol module 054

2. Title in original language

English Policy Impacts on Inequality

French

Spanish

Other language

3. Subtitle in original language

English Inequality and Axioms for its Measurement

French

Spanish

Other language

4. Summary

This tool illustrates the concept of desirable properties any inequality index should respect. In particular, it introduces the distinction between a positive and a normative approach to inequality analysis. Then, it discusses the role of axioms in inequality measurement and their conceptual meaning. Finally, using the Gini Index and the variance, a step-by-step procedure and numerical examples are introduced for operational purposes.

5. Date

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7. Module type

- Thematic overview
- Conceptual and technical materials
- Analytical tools
- Applied materials
- Complementary resources

8. Topic covered by the module

- Agriculture in the macroeconomic context
- Agricultural and sub-sectoral policies
- Agro-industry and food chain policies
- Environment and sustainability
- Institutional and organizational development
- Investment planning and policies
- Poverty and food security
- Regional integration and international trade
- Rural Development

9. Subtopics covered by the module

10. Training path

[Analysis and monitoring of socio-economic impacts of policies](#)

11. Keywords

capacity building, agriculture, agricultural policies, agricultural development, development policies, policy analysis, policy impact analysis, poverty, poor, food security, analytical tool, inequality, inequality axioms, inequality indexes, inequality measures, income inequality, income distribution, income ranking, welfare measures, social welfare, lorenz curve, lorenz dominance, theil index, gini index, scale invariance, translation invariance, principle of transfers, pigou-dalton principle, scale invariance, translation invariance, principle of population, decomposability

