



# Entropy based European income distributions and inequality measures

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## HIGHLIGHTS

- Information Theoretic Entropy recovery methods.
- Income probability distributions of micro income data for 16 European countries.
- Alternative to likelihood based methods that are fragile under model uncertainty.
- Derive the implied measure of inequality for each country.

## ARTICLE INFO

### Article history:

Received 26 September 2017

Received in revised form 5 September 2018

Available online xxx

### JEL classification:

D31

E21

C1

C10

C24

### Keywords:

Income probability distribution function

Micro income data

Information theoretic methods

Cressie–Read divergence

Entropy maximization

Pareto's law

(PDFs)

## ABSTRACT

In this paper, instead of likelihood based methods that are fragile under model uncertainty, we use entropy based methods on time-ordered household income data to recover income distribution information on European countries and obtain an inequality income measure. For information recovery, we use a family of information theoretic entropy divergence measures to obtain income probability density functions and the corresponding inequality measures, which reflect how European country based economic behavioral systems are performing, and in terms of dynamics have changed over time.

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## 1. Introduction

In this paper information theoretic entropy based divergence methods are used to investigate the heterogeneity and time paths of income probability density functions (PDFs) from European country based samples of micro household income data and to simultaneously obtain the implied measures of income inequality. Income probability density functions–distributions evolve from complex, uncertain, and volatile economic behavioral systems that are seldom in equilibrium. Since traditional

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likelihood methods<sup>1</sup> for obtaining income distribution estimates are fragile under model uncertainty [4–6], this means that behavioral system income distribution outcomes may best be viewed and analyzed in an information theory and probability context.

In economic behavioral systems, markets provide a basis for processing information and determining the value of the components in the income portfolio. At the economic unit-country level, the income probability density function-distribution contains information on how the market is functioning, how the allocation and distribution system is performing, and in terms of dynamics, how the economic system has changed and is changing over time. The distribution of income or wealth that results, is a based on a very complex set of market interactions, governmental policies and interventions, and changes that are institutional in nature.

As a basis for estimating, ordering and determining the informational content of countrywide income PDFs, likelihood is the common loss function used in econometric information recovery. However, the optimality of a given likelihood method is highly unstable with respect to inference under model uncertainty. In addition, the precise functional representation of the data sampling process cannot usually be justified from economic-behavioral theory. Given this situation, a natural solution is to use estimation and inference methods that are designed to deal with systems that are fundamentally ill posed and stochastic in nature and uncertainty and random behavior are basic to information recovery. Therefore, in this paper we use informational theoretic entropy based econometric methods and annual samples of European micro income data. In this entropy approach to information recovery, moment constraints provide a basis for representing our knowledge of the micro economic behavioral system in terms of a probability density function-distribution. Within this framework a unique country based entropy measure of income inequality results.

The study of income distribution recovery has a long history. In the search for a universal regularity in income and wealth, Pareto [7] originally suggested an exponential-power law income distribution to describe the allocation of wealth among individuals, and to demonstrate that a larger portion of the wealth of any society is owned by a small percentage of the people. Pareto's description of the nature of the income distribution is sometimes expressed more simply as the Pareto fat tail principle or the "80–20 rule", which says that 20% of the population controls 80% of the wealth. Power laws have been proposed as ergodic distributions for stochastic processes by Champernowne [8] and Levy and Solomon [9], to explain the Pareto exponential distribution of income. Many possible measures, such as the Gini concentration ratio, the Lorenz curve (see for example [10,11]) and the exponential distribution [12,13], have been proposed to measure income inequality and reflect the nature of the distribution of income. In addition, the dynamic nature of income distribution and the evolution of income inequality has been the focus of a growing empirical literature in the context of developed countries (for a survey see [14–18]).

Building on the productive efforts noted above, we contribute to this literature by presenting a uniform entropy based behavior-related method that simultaneously recovers country based income PDFs under uncertainty and the corresponding income equality-inequality measure, from samples of micro income data. We extend this literature by recovering country based probability density-income distribution functions that serve as a basis for determining how the economic systems are functioning and measuring the nature of income inequality. Traditionally, there is no commonly accepted definition of inequality and the basis for determining the underlying income distribution is often unrelated to the inequality measure. Thus, there are different interpretations of the inequality concept as well as existing questions about the underlying dynamics of income inequality, including the way in which income distributions and income equality-inequality change over time. From an empirical standpoint, a Eurostat data series of over one million household-country-year observations allows us to pursue some of these questions and to use a new adaptive intelligent behavior-causal entropy maximization conceptual framework and information recovery methods to recover income probability distributions and obtain measures of income European country based inequality.

Using tools associated with information theory and statistical physics, we argue in Section 2 that the probability distribution of income is given by the possible ways in which a collection of non-interacting micro incomes may occupy a set of discrete income states. Consistent with the data generation process, we use an information theoretic entropy based method (see [4,5]) and micro sample data to recover the unknown probability density-distribution function. Using micro-level income data from European countries that is described in Section 3, we investigate in Section 4 whether economic behavior and the nature of income inequality is captured by this entropy based distribution and inequality measure. In the empirical information recovery process of Section 4 we recognize the connection between adaptive intelligent behavior and causal entropy maximization in a self-organized open economic behavioral system. We use the Cressie-Read family of divergent measures to determine the nature of the distribution of the European country based micro income data for sixteen countries for the sample of years 2008 to 2013. In Section 5 we investigate in an income distribution and entropy measure context, the time ordered nature of income inequality for Sweden. Finally, in Section 6 we conclude and discuss the implications of the entropy based methods and the micro data sample-income distribution results for investigating income inequality.

## 2. An entropy-information recovery framework

As we focus on the recovery of the underlying (PDFs) from micro income data, we recognize and emphasize the behavior related nature of the observations. This means we recognize that like prices, incomes do not behave, but that people

<sup>1</sup> See e.g., McDonald's [1] generalized beta distribution of type 2 (GB2) as being one of the most popular and versatile used in the literature [2,3]. A comparison along a criterion with GB2 is an avenue of future research.

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