



# Evolutionary model of the personal income distribution

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## ABSTRACT

The aim of this work is to develop a qualitative picture of the personal income distribution. Treating an economy as a self-organized system the key idea of the model is that the income distribution contains competitive and non-competitive contributions. The presented model distinguishes between three main income classes. 1. Capital income from private firms is shown to be the result of an evolutionary competition between products. A direct consequence of this competition is Gibrat's law suggesting a lognormal income distribution for small private firms. Taking into account an additional preferential attachment mechanism for large private firms the income distribution is supplemented by a power law (Pareto) tail. 2. Due to the division of labor a diversified labor market is seen as a non-competitive market. In this case wage income exhibits an exponential distribution. 3. Also included is income from a social insurance system. It can be approximated by a Gaussian peak. A consequence of this theory is that for short time intervals a fixed ratio of total labor (total capital) to net income exists (Cobb–Douglas relation). A comparison with empirical high resolution income data confirms this pattern of the total income distribution. The theory suggests that competition is the ultimate origin of the uneven income distribution.

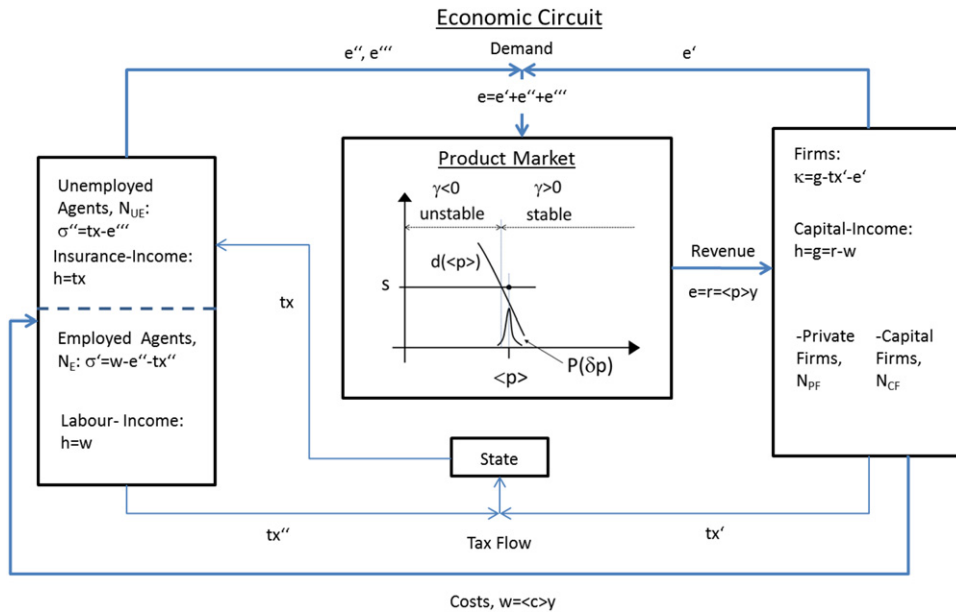
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## 1. Introduction

The investigation of the income distribution has a long history. Irrespective of differences in culture, language, county and history, the income distribution is seen to follow a universal pattern [1]. Pareto suggested that the income distribution is governed by a power law [2]. However, later studies found that this relationship applies only to the top income of 1%–3% of the population. Gibrat proposed that the income distribution for the majority of the population obeys a log-normal distribution caused by a multiplicative growth process [3]. Recently Yakovenkow and Dragulescu found from empirical investigations that the lower part of the personal income distribution is rather determined by an exponential (Boltzmann–Gibbs) distribution [4,5]. There are several attempts made to explain the income distribution. For an overview see for example Ref. [6]. Also simulations are used to understanding the key processes leading to this income distribution structure [7–9]. The presented theory, however, establishes an alternative approach. It suggests that the empirical findings have their origin in the competitive or non-competitive dynamics of specific income classes.

This can be understood as follows. Starting point of the model is to treat an economy as a self-organized system, consisting of a network of money carrying agents. The creation and exchange of goods induces a financial flow and generates the income. In order to reduce the complexity, we confine here to a representative (effective) good, for which several variants may exist denoted as products (brands). Following the synergetic approach to self-organization the dynamics of a self-organized system is essentially determined by its slowly varying variables, so-called slow modes [10]. This comes from the fact that the evolution of fast varying variables are governed by constraints generated by the slow modes of a system. Slow modes can be written in terms of conservation equations. However, for an economic system conserved quantities

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**Fig. 1.** Schematically displayed is the economic circuit of the representative good as used in the model. The arrows indicate the financial flows. The insert in the product market shows schematically the relation between supply  $s$  and demand  $d(\langle p \rangle)$ . The mean price adapts via price fluctuations indicated by the distribution  $P(\delta p)$ . For  $\gamma > 0$ , the market is stable due to competition between product variants of the representative good.

occur only within short time intervals. Therefore, a separation of the time scales is applied. For short time intervals the total number of agents  $N$  forming the economic network, the total amount of (liquid) money  $M$  and the total number of product variants  $K$  can be viewed as slowly varying. The model takes also into account that the total capacities to manufacture the representative good vary slowly. This is due to the fact that capacity variations are associated with time consuming investments. Demand is considered here as the generation of potential consumers (agents) willing to purchase the representative good for a given price. When potential consumers meet available units of a product purchase events occur with a certain probability rate. But because the supply is slowly varying it turns out that also the purchase rate and the mean price are slow variables. Since the slow modes govern the product market for short horizons they also determine the income distribution.

The financial flow generated by supply and demand of the representative good is called the economic circuit [11]. This circuit creates different income classes as schematically displayed in Fig. 1. One income class is associated with firms supplying the good. Their income, called capital income, is determined by the competition between products of the representative good. As derived below, the unit sales of products are governed by a replicator dynamics [12]. In other words, products are similar to species in ecological systems as suggested originally by Modis [13]. But firms are more than just the sum of their products. Firms have the ability to take advantage of their size to create and purchase new products in order to offer them to the market. In biological terms, firms are not species but correspond rather to genera. And from biological genera it is known that their growth is governed by an additional growth process called preferential attachment. Taking this effect into account the firm size distribution in terms of unit sales exhibits a lognormal distribution for small firms and a power law tail for large firms as shown in a previous paper [14]. Because the profit of firms is proportional to its unit sales, private firms will have a similar structure of the personal income distribution.

However, next to private firms there are other income classes. A major group are wage receivers. Modern economies are based on the division of labor. Therefore labor markets can be viewed as diversified. In this case the income of employees is rather the result of (individual) negotiations between employees and employers than due to direct competition. Taking advantage from the slow modes of an economy it can be shown that labor income can be described by a Boltzmann–Gibbs distribution. Also included in this model is the income caused by a social insurance system.

The purpose of the paper is to derive the distributions of the individual income classes. Note that the model is not complete because it focusses on financial flows related to the economic circuit. Suppressed are other sources of income, generated for example in financial markets. Therefore we obtain merely a qualitative picture of the total personal income distribution. The paper is organized as follows: In the next sections the economic circuit is discussed followed by a derivation of the dynamics of a free product market. From these considerations the personal income distribution is established. In order to show the applicability of the model a comparison with empirical data of the income distribution is performed, followed by a conclusion.

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