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Title of dissertation:

Application of nonlinear Langevin equation,
Fokker–Planck equation, and random walk models to
modelling of household incomes in Poland and the
European Union

Dissertation directed by:
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ABSTRACT

My phd thesis is an original selection, reformulation and extension of the canonical models of statistical physics dedicated for study the properties of systems beyond the traditional physics. Although, the research areas covered by my thesis are traditionally the domain of economy and sociology, these areas belongs today to the research mainstream of econo- and sociophysics.

More precisely, the subject of my thesis concerns the dynamics of household incomes in Poland and the European Union during the time of crisis and beyond. I conducted my main analysis both within the Langevin stochastic dynamics and Fokker–Planck equation. In addition, I considered selected models of random walks where household income is treated as a time-dependent random variable.

In my thesis I obtained valuable results by analysing the wealth and income of Polish households as well as households of societies belonging to the European Union. This analysis was based both on empirical data (from the years 2004–2010) and on selected models developed within the statistical physics, financial mathematics and econometrics concerning for example, power-law, exponential and log-normal distributions that is, the Pareto law, collision models, the Rules of Proportionate Growth and Generalised Lotka–Volterra model. It should be emphasised that these models are multivariable and dynamic (in the sense of stochastic dynamics) – the linear and nonlinear Langevin dynamics are their prominent examples.

The main aim of my thesis is a deeper understanding, including quantitative description (parametrised by a small number of values possible to determine from the empirical data) of the mechanisms of gaining income and enrichment or impoverishment of the societies both Poland and the European Union. This is an extremely important goal, the achievement of which can specify the pathways of development of the European Union and Poland.

The main result of my research is a generalisation of the well known Yakovenko model and thus the principal formula of Yakovenko. The formula is based directly on the equilibrium solution of the corresponding Fokker–Planck equation. This allowed us to study the income of all three society classes and not only two ones as the original Yakovenko model made. In other words, I have obtained the formula which is able to describe the income of all European Union households belonging to the low-, medium- and high-income society classes. It should be emphasised that, despite many attempts aimed for theoretical description of the empirical income distributions of individuals or households, so far I have proposed model which is the first that gives an effective, consistent and comprehensive description of the household incomes of all society classes. My low-parameter model is a culmination of the current knowledge regarding the analysis of household incomes.

My research has some significant pragmatic aspect, as it can support, for instance, the construction of the appropriate tax and retirement systems. Furthermore, my research can estimate the structure of the market demands.

My dissertation consists of four complementary chapters:

- the first chapter, where I presented a critical overview of theoretical models used so far to analytical description of society incomes;

- the second chapter, where I developed efficient, consistent and comprehensive formalism describing the society incomes;
- the third chapter, where I analysed empirical data on the annual disposable income of Polish households in the years 2004–2010, in particular by comparison of the empirical data with theoretical models. In this chapter I also focused on the analysis of properties of commonly used models;
- the fourth chapter, where I presented the detailed procedure for joining different databases containing empirical income data. Then, with a complete income dataset of all society classes in the European Union, I have carried out an extended (in comparison with that shown in Section 3) analysis for the years 2005–2010. To perform this analysis I used my models, having well motivated opportunity to make their thorough review and discuss their useful properties.

In seven appendices I discussed the Pareto distribution (Appendix A and B) and the Generalised Lotka–Volterra model (Appendix C). I also enclosed a description of the Weibull method (Appendix D). In the appendices E and F I included additional information on the analysis of empirical data on household incomes in the European Union. Furthermore, in the Appendix G I carried out a thorough discussion concerning the procedure of joining the databases. Moreover, Appendix H contains an overview of the Gini coefficient.