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"Reverse Engineering" in Econophysics

M.P. Hanias, Department of Electrical Engineering, Eastern Macedonia and Thrace Institute of Technology, Kavala, Greece
L. Magafas, Department of Electrical Engineering, Eastern Macedonia and Thrace Institute of Technology, Kavala, Greece
S.G. Stavrinides, School of Science and Technology, International Hellenic University, Thermi-Thessaloniki, Greece

ABSTRACT

The work presented here is a paradigm of EconoPhysics, i.e. of research in the area of finance and economics by applying physical models, in this case chaos theory. A specific analysis of a macroeconomic model proposed by Vosvrda is presented. The Vosvrda model is an idealized macroeconomic model, combining the savings of households, Gross Domestic Product and the foreign capital inflow. It is simulated by three autonomous differential equations. According to this model, there are six parameters, having their values regulating the system behavior (parameters of Vosvdra). Using artificial noisy data for simulating real data and using an inverse modelling procedure, the authors have fitted and tuned the parameters of Vosvdra differential equations to achieve more accurate solutions. The relevant resultant evaluation showed that the system is a chaotic one, even though for the same values proposed by Vosvrda. Finally, this chaotic behavior has provided the capability to expand the time horizon of the solution, thus achieving reliable forecasting for the system.

KEYWORDS

Chaos, Differential Equations, Forecasting, Macroeconomic Model

INTRODUCTION

The relatively high level of Public Debt to Gross Domestic Product (PD/GDP), in almost all developed countries, is becoming one of the most important economic problems that has to be resolved or at least controlled, in the near future. As an example, the G-20 overall public debt (PD) had been increasing continuously since the energy crisis in the middle of 70's till the finance crisis of 2008; and since then it has demonstrated a noteworthy acceleration leading to surpassing the dangerous level of 100% of the GDP (Abbas, Belhocine, ElGanainy, & Horton, 2010).

In the case of Europe, some countries of Eurozone, like Greece, Italy and Cyprus, presented extremely high level of the ration of PD/GDP. In the case of Greece this reached 179% (https://tradingeconomics.com/greece/indicators.). This value of the Greek Public Debt caused a strong debate between Eurozone and the International Monetary Fund (IMF), on whether this level of PD is sustainable for the Greek economy or the need for a haircut appears to be inevitable. It is clear that the ability of the above described countries to refund their debts is of great importance, if not crucial, since in the opposite case the possibility of new finance turbulences in the world economy could become a reality.

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In order to investigate if a country's debt can be refunded, one must know if specific conditions are satisfied. One way to do so is to extract information from real data, applying inverse fitting to the system of differential equations that produce the real data. It is apparent that this particular approach needs further study and research, taking into account more parameters and/or different methods of evaluation.

In this work the typical macroeconomic model proposed by Vosvrda, which involves the savings of households, the Gross Domestic Product and the foreign capital inflow, was utilized as a paradigm of a general methodology with which we are able to extract the necessary conditions needed, for the prediction of the systems variables. As an application the ability of the specific economical system to refund its debt, is predicted.

METHODOLOGY

The proposed hereby methodology for predicting specific characteristics of a system by utilizing past-time data, by exploiting nonlinear dynamics for expanding the time horizon, is briefly aposed (in the form of steps) in the lines that follow:

Step 1: Few real data for all the variables of the system is collected.
Step 2: The proper set of differential equations as this is "guessed" by theoretical considerations or by trial and error, is constructed.
Step 3: Initial values of all the parameters are set; some of them maybe partially known.
Step 4: The system's set of differential equations is solved, and the solution is compared to the real data (validation process).
Step 5: The inverse modeling procedure is applied for all or some of the system's parameters.
Step 6: The system's set of differential equations is solved again with the new fitted parameter values (testing).
Step 7: Solving the set of differential equations is de facto expanding the time horizon, thus forecasting of the values of one or all of the variables is possible.

This methodology supposes that we have collected some real data for all variables of the specific system. But in case where we have collected one's variable data only, then we must expand the methodology to include the other unknown data. In this case we can reconstruct the phase space according Taken's theorem (Abarbanel, Brown, & Kadtke, 1990; Takens, 1980). From the reconstructed timeseries one can choose some points as real data. Then we can repeat the steps all over again.

It is apparent that this methodology is a kind of reverse engineering, exploiting at the same time the ability that deterministic chaotic systems have, to reconstruct the equivalent dynamics by one or more system variables.

A CASE STUDY - THE MACROECONOMIC MODEL

In the literature there are many autonomous systems of three differential equations that describe economical models (Buali, 1990; Pribylova, 2009). The Vosvrda system is one of them (Pribylova, 2009; Voˇsvrda, 2001) and it describes an idealized macroeconomic model with foreign capital investment. It is represented by three autonomous differential equations, as follows:

$$\frac{dS}{dt} = aY + pS\left(k - Y^2\right) \quad (1)$$

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