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System Dynamic Macroeconomic Model - The Case of Croatia

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Abstract: - This paper is about decision support with system dynamic simulation. System dynamics is a method that explores the behavior of complex dynamic systems with feedback loops. It is a method of continuous simulation, suitable for work with highly aggregated variables, and especially suitable for simulation modeling of economic systems. The purpose of this paper is to present a simulation model of the national macroeconomic system. The paper focuses on developing a simulation model, rather then suggesting some concrete macroeconomic policy, although the paper does contain experiments with some simple scenarios regarding the monetary policy. The model is primarily focused on changes of GDP, foreign debt and budgetary deficit, which stand for the main problems of Croatian economy. The market is positioned in the center of the model, and market balance is achieved on the aggregated level of supply and demand, expressed in quantities. The model also includes the sub-model of government budgeting with basic categories of accompanied incomes and expenditures, as well as sub-models of employment, debt financing, inflation and exchange rate. The last part of the paper presents a simulation experiment that follows a simple scenario about the government budget deficit financing.

Key-Words:- system dynamics, modeling, simulation, macroeconomic model.

1 Introduction

Economic systems contain as many as 100 or more variables that are known to be relevant and believed to be related to one another in various nonlinear fashions. The behavior of such a system is complex far beyond the capacity of intuition. Computer simulation is one of the most effective means available for supplementing and correcting human intuition.

A computer model differs principally in complexity, precision and explicitness from the informal subjective explanation or "mental model" that people ordinarily construct to guide their actions toward a goal. It is an account of the total set of forces that are believed to have caused and to sustain some problematic state of affairs. Like the informal mental model, it is derived from a variety of data sources including facts, theories and educated guesses. Unlike the mental model, it is comprehensive, unambiguous, flexible and subject to rigorous logical testing.

The flexibility of a model is its least understood virtue. If two people disagree about some aspect of the causal structure of a problem, they can usually in a matter of minutes run the model twice and observe its behavior under each set of assumptions. They may, on the basis of its behavior, be forced to admit that the other one was correct. Very often, however, they will both discover that their argument was trifling, since the phenomenon of interest to them may be unchanged by a change in assumptions.

The system dynamics modeling approach begins with an effort to understand the system of forces that has created a problem and continues to sustain it. Relevant data are gathered from a variety of sources. As soon as a rudimentary measure of understanding has been achieved, a formal model is developed. This model is initially in the format of a set of logical diagrams showing cause-and-effect relationships. As soon as feasible the visual model is translated into a mathematical version. The model is exposed to criticism, revised, exposed again and so on in an iterative process that continues as long as it proves to be useful. Just as the model is improved as a result of exposures to critics, a better understanding of the problem is achieved.

“By closely observing the structures and policies in business and government, simulation models can be constructed to answer questions about business cycles, causes of major depressions, inflation, monetary policy, and the validity of descriptive economic theories. A system dynamics model, as a general theory of economic behavior, now endogenously generates business cycles, the economic long wave, and growth. A model is a theory of the behavior that it generates”[1].

2 Modeling macroeconomic systems

A computer model constructed and used by an economic policymaking group may have the following advantages [1]:

- It requires economic policymakers to improve and comp1ete fully the rough mental sketch of the causes of the problem that they inevitably have in their heads.
- In the process of formal model-building the builders discover and resolve various self-contradictions and ambiguities among their implicit assumptions about the problem.
- Once the model is running, even in a rudimentary fashion, logical "bootstrapping" becomes possible.
- Once an acceptable standard of validity has been achieved formal policy experiments reveal quickly the probable outcomes of many policy alternatives and "what if" situations can be explored.
- An operating model is always complete, though in a sense never completed. Unlike many planning aids, which tend to be episodic and terminal, a model is organic and iterative.
- Sensitivity analysis of the model reveals the areas in which genuine debate is needed and guides empirical investigation to important questions.
- A model can be used to communicate with people who were not involved in building the model.

2.1 System Dynamics

System dynamics is the application of feedback control systems principles and techniques to organizational, managerial and socioeconomic problems [4]. For macroeconomic usage, system dynamics advocates seek to integrate the several functional areas of a national economy into a conceptual and meaningful whole, and to provide an organized and quantitative basis for designing more effective macroeconomic policy.

Three advances made feasible the system dynamics approach:

- Advances in feedback systems design and analysis.
- Progress in computer simulation techniques.
- Increasing experience in the modeling of complex systems.

First in importance were advances in the understanding and analysis of information-feedback systems. These originated in engineering experience with simple mechanical and electromechanical servomechanisms and were extended on complex electronic systems which included numerous subsystems and thousands of components. As the subtleties of information feedback systems became more widely known, the existence of feedback mechanisms in economic systems began to be explored.

Another basic development that underlies system dynamics practice is the use of simulation methods. For many years, simulation has been an important part of engineering design. With the advent of reliable, high-speed digital computers, the simulation of large economic systems became practical. The restrictions that had constrained the size and form of desired mathematical models were now eliminated.

Professor Jay W. Forrester had pioneered the beginning of the industrial dynamics program and the development of a system dynamics research methodology, the creation of a philosophy and pilot applications.

The system dynamics philosophy rests on a belief that the behavior (or time history) of an organization is principally caused by the organization's structure. The structure includes not only the physical aspects of system and his process but, more importantly, the policies and traditions, both tangible and intangible, that dominate decision-making in the organization. Economic systems containing these characteristics display complicated response patterns to relatively simple system or input changes. The analysis of large nonlinear systems of this sort is a major challenge and effective and reliab1e redesign of such a system is still more difficult.

A second aspect of the system dynamics philosophy is the concept that organizations are viewed most effectively in terms of their common underlying flows instead of in terms of separate functions.

The system dynamics methodology was developed to make practicable the evolving philosophy. The tools of flow diagramming, mathematical modeling, and computer simulation were used and modified to fit the new needs. Formal flow diagramming and equation-writing methods were created for the next steps of most system dynamics projects. Both the flow diagrams and equations represent organizational relationships as falling into two categories-levels and rates. The levels represent those aspects of the real world in which accumulations of resources exist. The second variable type, the rate, includes all activities within the system.

Once the organization problem has been represented in levels and rates, most system dynamics projects employ computer simulation.

2.2 Macroeconomic Background

The major macroeconomic issues are [5]:

- Economic growth and living standards.
- Productivity.
- Recessions and expansions.
- Unemployment.
- Inflation.
- Economic interdependence among nations.

The exposed system dynamic macroeconomic model should allow modeling of most macroeconomics issues, especially economic growth, recessions and expansions, unemployment, inflation, exports and imports.

Although many factors contribute to economic performance, government macroeconomic policies are surely the most important because they affect the performance of the economy as a whole. There are three major types of macroeconomic policy:

- Monetary policy.
- Fiscal policy.
- Structural policy.

The exposed system dynamic macroeconomic model should primarily serve as a way to predict effects of monetary and fiscal policies, without getting into the problems of structural policy.

Among very few papers from this field there is one focused on monetary policy based on the Polak's monetary model [2].

The basic Keynesian model, which is theoretical foundation of exposed system dynamic model, is built on two key assumptions:

- Aggregate demand fluctuates. Total planned spending in an economy, called *aggregate demand*, depends on the prevailing level of real GDP as well as other factors. Changes in either real GDP or in other factors that affect total spending will cause aggregate demand to fluctuate.
- In the short run, firms meet the demand for their products at preset prices.

Firms do not respond to every change in the demand for their products by changing their prices. Instead, they typically set a price for some period, and then *meet the demand* at that price which means that firms produce just enough to satisfy their customers. Prices should be changed if the firms benefit of doing that.

In the Keynesian theory, output at each point in time is determined by *aggregate demand*, which is total planned spending on final goods and services that consists of:

- Consumer expenditure or consumption,
- Investment,
- A government purchase,
- Net exports.

Increases in output, which imply increases in income, cause consumption to rise. As consumption is part of aggregate demand, aggregate demand depends on output as well.

According to the assumption of the basic Keynesian model, during the short-run period in which prices are preset, firms produce an amount, or GDP that is equal to aggregate demand. This equilibrium is shown in figure 1.

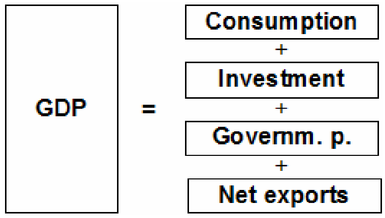

Fig. 1 GDP and aggregate demand equilibrium

To model the market equilibrium, the basic model is extended with imports on both sides, which is shown in figure 2. Demand is different from aggregate demand from the basic Keynesian model and is equal to supply which represents an auxiliary measure of market equilibrium.

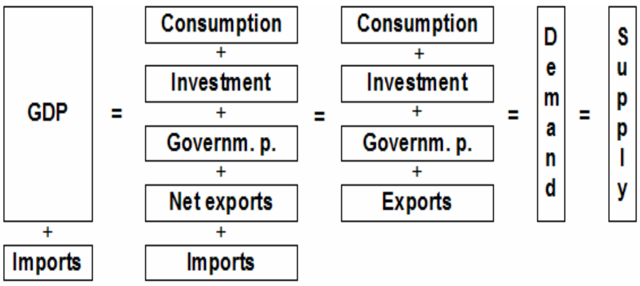

Fig. 2 Extended GDP and aggregate demand equilibrium

On the other hand, GDP can be measured as total income as shown in figure 3.

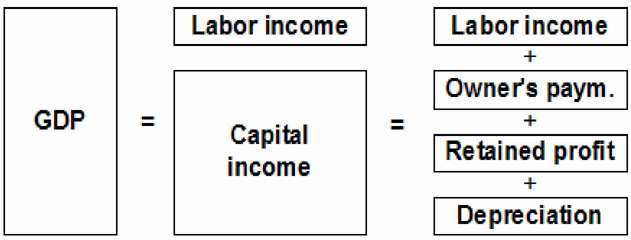

Fig. 3 GDP expressed by total income

The exposed system dynamic macroeconomic model uses both methods for measuring GDP, expenditure method and total income method.

3 System Dynamic Macroeconomic Model (SDMEM)

3.1 Structural Model for SDMEM

The structural diagram for SDMEM is hierarchically structured at three levels, and shown in few figures, from figure 4 to figure 15. The sign at the arrowhead determines the mutual effect of variables. Plus denotes positive effect and minus denotes negative effect.

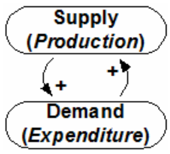

Fig. 4 SDMEM top structural diagram (level 1)

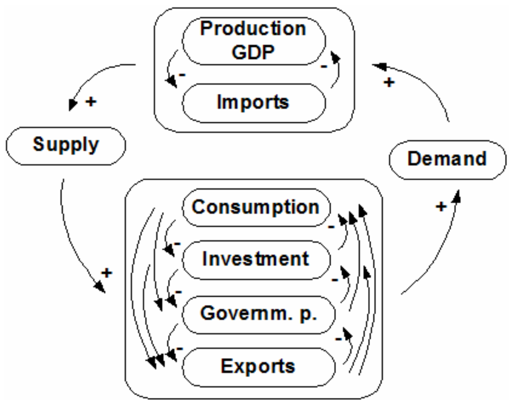

Fig. 5 SDMEM decomposed structural diagram (level 2)

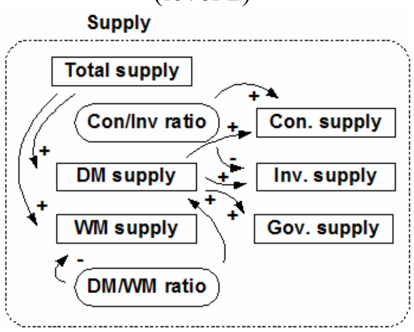

Fig. 6 SDMEM supply sub model structural diagram

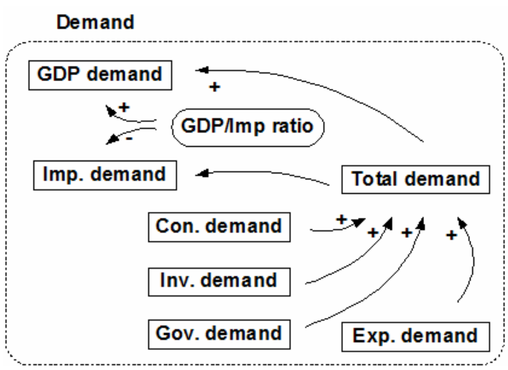

Fig. 7 SDMEM demand sub model structural diagram

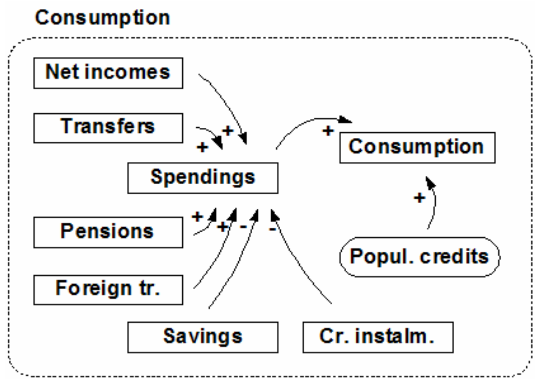

Fig. 8 SDMEM consumption sub model structural diagram

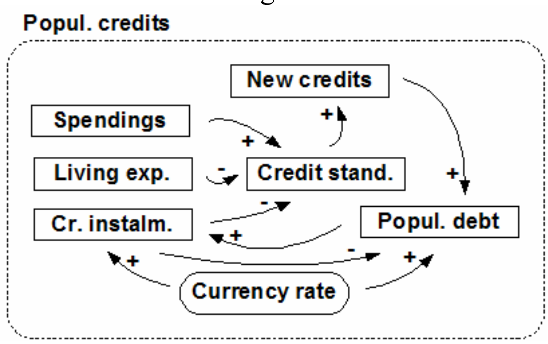

Fig. 9 SDMEM population credits sub model structural diagram

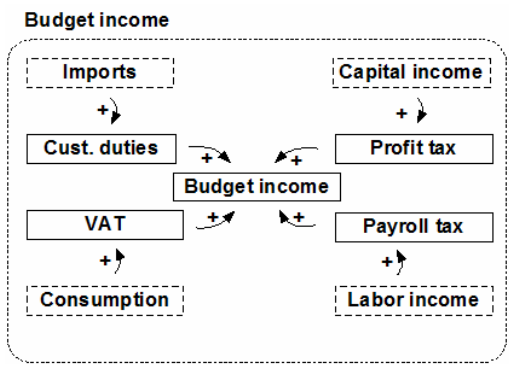

Fig. 11 SDMEM budget income sub model structural diagram

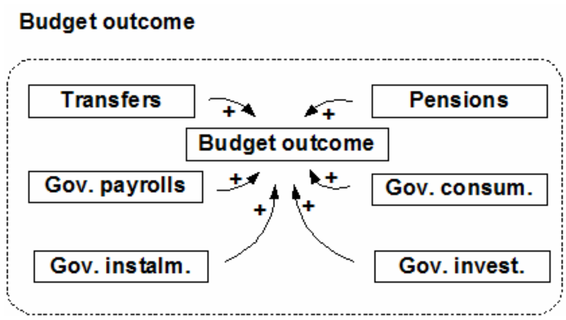

Fig. 12 SDMEM budget outcome sub model structural diagram

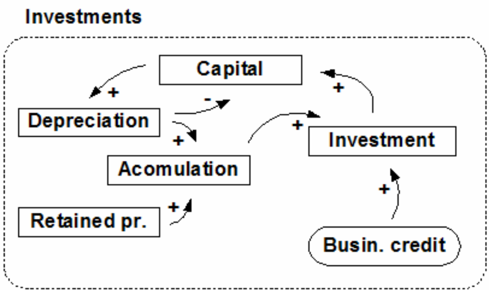

Fig. 13 SDMEM investments sub model structural diagram

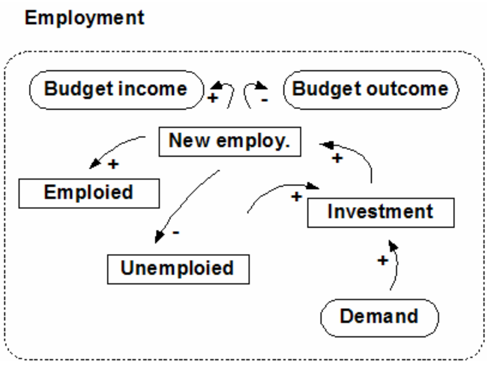

Fig. 14 SDMEM employment sub model structural diagram

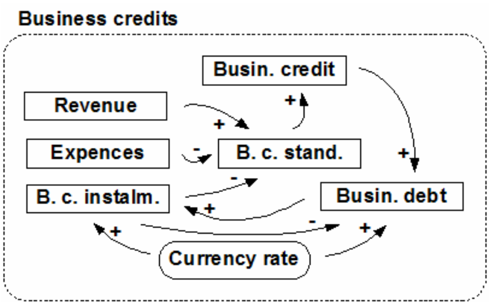

Fig. 15 SDMEM business credits sub model structural diagram

3.2 Flow Diagram for SDMEM

POWERSIM is object-oriented software used for building flow diagrams for SDMEM [6]. By the use of few symbols, an exact mathematical equation is presented describing the dynamics of the observed system. Due to complexity of the modeled system, the SDMEM flow diagram is too complex and large to be presented as a whole, so only one sub-model of SDMEM flow diagram is shown on figure 16.

Also, the structural flow diagram created by POWERSIM tool is at the same time mathematical-computing non-linear and very complex model of the same complex process the dynamics of which cannot be adequately observed by classical methods.

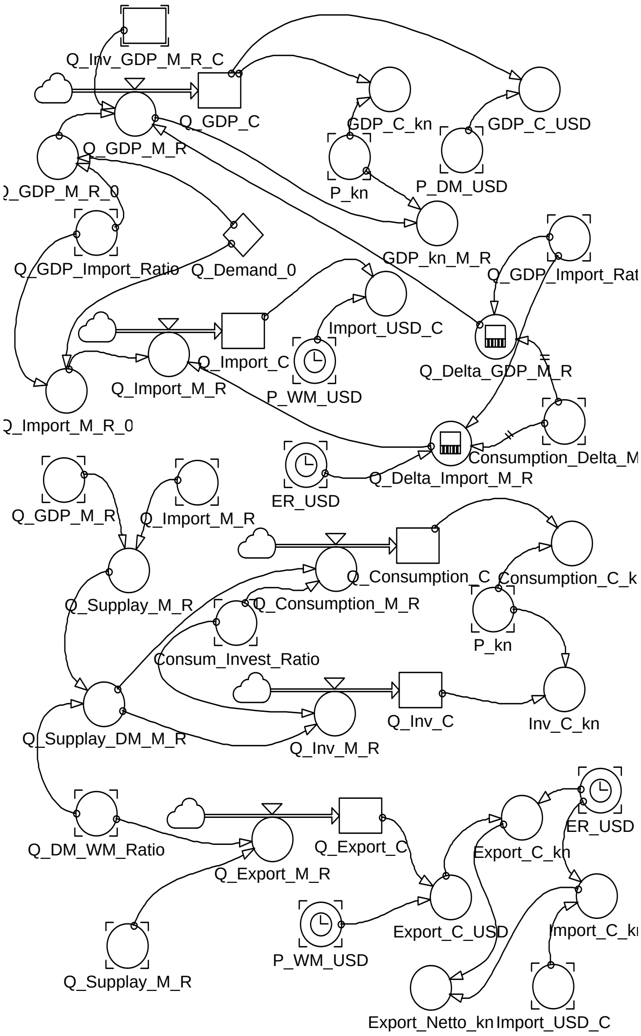

Fig. 16 Part of SDMEM flow diagram for market equilibrium

3.3 SDMEM Validation

The validity of the model has been valuated by the use of Croatian macroeconomic indicators for year 2003 [7]. Due to complexity of the modeled system, there is lot of SDMEM outputs, and only two typical ones are shown in the figures 17 and 18.

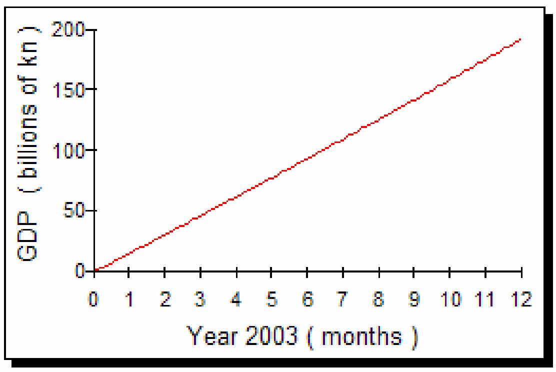

Fig. 17 SDMEM output for Croatian GDP

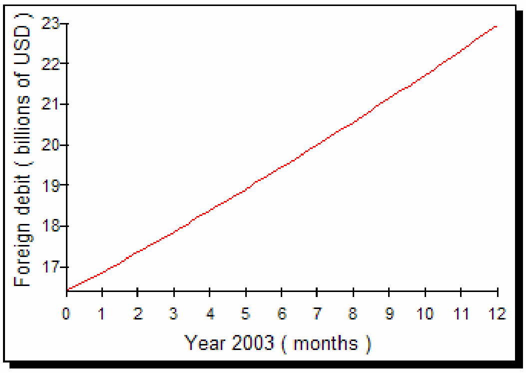

Fig. 18 SDMEM output for Croatian foreign debt

3.4 Experiment

As it was said in the introduction, once an acceptable standard of validity has been achieved, formal policy experiments quickly reveal the probable outcomes of many policy alternatives; navel policies may be discovered; "what if" situations can be explored.

In this case, the conducted experiment uses a very simple scenario, which can be practically irrelevant. The model consists of a parameter which is used to regulate the relation between financing of budgetary deficit by using foreign debt financing and by primary emission. In the basic model the value of this parameter is “1”, which presents a situation where the entire deficit is financed by using foreign debt financing. In the scenario presented here, the value of this parameter is “0”, or in other words, it is assumed that the entire budgetary deficit is financed using only primary emission.

The thesis that wants to be examined by the model is as follows. Besides the reduction of foreign debt, such a measure would also trigger a rise in the rate of inflation, which would affect the exchange rate of the national currency. This would cause the rise in prices of imported goods, which would, trough the effect of substitution, open up space for the increase of domestic production, the growth of GDP and the reduction of foreign debt growth.

The result of the experiment is presented by using only two indicators, as shown in figures 19 and 20.

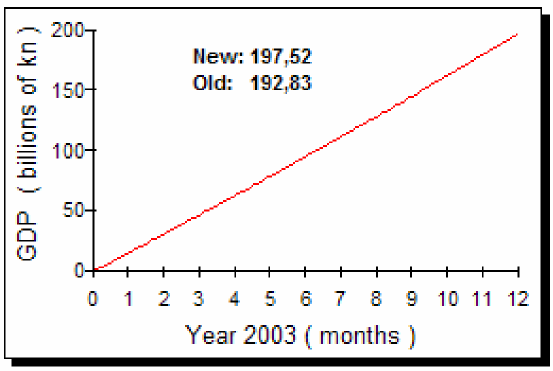

Fig. 19 SDMEM scenario output for GDP

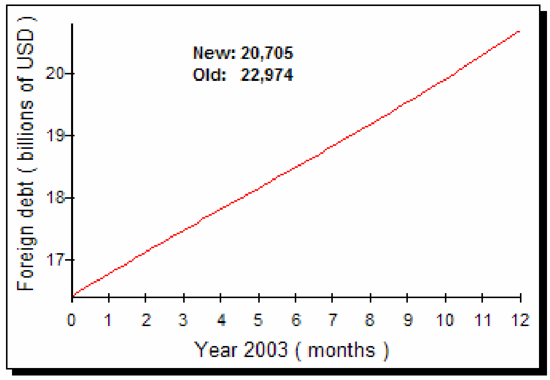

Fig. 20 SDMEM scenario output for foreign debt

As it was already pointed out, the purpose of this paper is not to make macroeconomic conclusions, so the results of this experiment will not be analyzed.

4. Conclusion

A computer simulation model of the kind described here is a powerful conceptual device that can increase the role of reason, at the expense of rhetoric in the determination of economic policy. A model is not, as it is sometimes supposed, a perfectly accurate representation of reality that can be trusted to make better decisions than people. It is a flexible tool that forces the people who use it to think harder and to confront one another, their common problems and themselves, directly and factually.

Implementation of this methodological approach, which will provide new insights in the behavior dynamics of non-linear cause-effects links between the macro economical variables of the national economy. The model should be exposed to criticism and revised and so on in an iterative process that continues as long as it proves to be useful.

The exposed system dynamic macroeconomic model (SDMEM) can be the starting point for more complex macroeconomic modeling and research.

References:

[1] Forester, J.W., *Economic Theory for the New Millennium*, Plenary Address at the 21st International System Dynamics Conference, New York 2003

[2] Grcic, B., *The Polak’s Macroeconomics Monetary Model*, Proceedings of the 19th International Conference of System Dynamics Society, Atlanta 2001

[3] Harington, H. J., Tumay, K., *Simulation Modeling Methods*, McGraw-Hill, New York 2000

[4] Frank, H. R, Bernanke, S. B., *Principles of Economics*, McGraw-Hill, New York 2001

[5] Roberts, B. E., *Managerial Applications of System Dynamics*, Productivity Press, Cambridge, 1978

[6] http://www.powersim.com;

[7] http://www.hnb.hr;