The Main Principles of Simulation Modeling of the Sustainable Development Complexes System: Case of World Economy

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Abstract. The phenomenon of states changes of the world economy during the last 200 years shows that there is a certain 70-year regularity in its development, which is expressed in increased structural complexity of the global economic system every 70 years. The development happens after certain periods of bifurcation (up to 50 years) accompanied by the lower rates of economic development, and periods of adaptation (up to 20 years) with the higher rates. The theoretical justification of this process shows that the increased structural complexity of the global economic system is the external manifestations of the self-organization process in a large complex system we call the "world economy". The "world economy" is regarded as global economic environment where countries and their group organizations are ordinary agents. Every agent has the same properties as the system: they can be open, non-equilibrium, dissipative, self-organizing; they can also have the aim – to maintain integrity through the main function (development). We can watch the fractal symmetry of all general properties ranging from the global system to its ordinary agent. Development, the main function of the system, is viewed as the movement of economic environment. Basing on the assumption about maintaining boundary limits of system stability we solve the task of stable movement of environment and sustainable development of the global civilization in the context of fixed main properties and system characteristics. On the basis of outlined properties we make a mathematical model of non-linear dynamic system – development of the global system.

Keywords: sustainable development, the self-organization, global system.

1 Introduction

Researches having been made by different scholars defined civilizations of the XXIst century. They are united into three local formations due to ethical, cultural and other features: Eurasia, North America and Oceania, Africa and the Middle East. The modern humankind is known to have faced a number of insoluble civilization problems which can cause destructive global processes.

First of all the religious, ethical and cultural conflicts are connected with different views on material side of civilization. The revenue gap between "the gold billion"

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population and other people is increasing. The control over allocation and use of scarce resources of the planet, first of all energy resources, relates to the conflict. There also exists a threat of ecological catastrophe. Low control over using weapons can lead to provoking local war conflicts to which countries having weapons of mass destruction can be involved.

It is obviously that the planet is a single home for all kinds of civilizations and for any social form of human's life activity. The main element in their coexistence without conflicts is the rules of interaction in the context of global system. The global system is a social system with structures – institutions that define the rules of interaction between countries (ordinary agents) of the global system.

Countries being ordinary agents of a social system (the global system) form regional and civilized systems. Every outlined local civilization can be viewed as group unions of countries that participate in international exchange of resources on the basis of international labor division. Thus, functioning of the global system that is based on existent regional and global institutions can be considered as regional and global institutions.

In the context of growing conflict tendencies of the XXIst century it is getting evident that existent institutions of the global system – supranational organizations and the system of international exchange of resources – do not provide development of the global civilization without conflicts. Therefore the most urgent task of nowadays is to make a forecast as to forming such social institutions that can guarantee coexistence of local civilizations without conflicts as well as sustainable development of the global system of the XXIst century.

The system of rules about interaction between civilizations as a political structure of the global system of the XXIst century on the basis of the common planetary constitution can be referred to these institutions. The system of international monetary and financial relations that is the basis for exchange of resources among civilizations should be stated in the common planetary constitution as well.

"The global system" system is aimed at maintaining its homeostasis or keeping humankind safe. Sustainable development of humankind lies in maintaining the global system integral for a long period of time. The necessary condition for this sustainable development is institutions which provide compromise base for interaction between local civilizations within the global system. To solve this task we need to define conditions which form both stability of a social system "the global system" and boundary limits of stability ensured by rules of interaction and in the context of which sustainable development occurs.

Thus, the forecast concerning sustainable development of the global civilization is the task of forecasting and forming institutions of the global system which can provide sustainable development of humankind.

The solution of the task about defining conditions of sustainable development of "the global system" system helps us to make the following conclusions:

- general approach allowing us to describe the main properties of "the global system" in a simplified form and its development with indicating feature parameters.
- mathematical formalization of the global system and its development basing on outlined characteristics as a non-linear dynamic system.

- making simulation modeling on the basis of laid down system of differential equations describing development of the global system.
- analysis of experiment results that can help to realize the following items:

– about the character of the global system behavior in the process of development.
– about the main system properties that form the process of development and its stability.
– about conditions for system functioning; the conditions have to be implemented to provide stability of development.

2 Sustainable Development of the Global System: System Approach

The author of the monograph "Self-organization of the World Economy" formulated the concept of development and self-organization of a social system the world economy (the global system) and made the corresponding model. The model represents the main characteristics of the system itself and its development. The model is represented in figure 1.

The system development is regarded as the process of changes in system states. Every system state has a structural and quantitative characteristic and specific time interval during which the structure keeps its integrity.

The model of the world economy development describes the system behavior within the period 1825-2035.

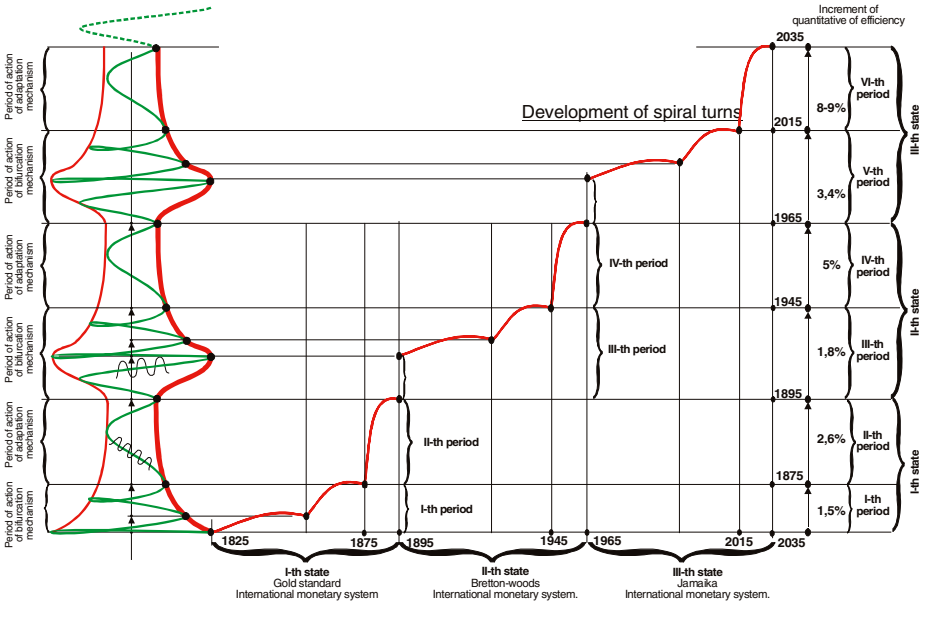

Fig. 1. The model of development and self-organization of World economy for interval of time 1825-2035 years

The idea about development process lies in the base. The process is considered as accumulating structural information on the basis of mechanism of self-organization as the result of struggle between two contrary tendencies: organization and disorganization. Definite structural and quantitative characteristics allow us to define three states of the world economy system in the process of its development. The first two states are real whereas the third one is predicted. The structural characteristic for every state is the system of international monetary and financial relations that function during specific time interval. Political structure of the global system – availability or absence of supranational institutions of regulating interactions among ordinary system agents as to exchange of resources on the basis of international labor division – can also be referred to structural characteristics.

The process of GDP growth for countries that participate in international exchange of resources can be called the quantitative characteristic. Countries making up the so-called "triad": Europe – the USA – Japan are taken as the base as more than 60% of world goods turnover during specific time interval falls on these countries.

Every state of the global system corresponds to a 70-year cycle of development. Every cycle combines conflict as well as non-conflict phase of development. A conflict phase is implemented through the bifurcation mechanism of development and low rates of GDP growth. Non-conflict phase is implemented through the adaptation mechanism of development and uneven increase in GDP. Every phase of a cycle corresponds to a definite period of development that changes each other like mechanisms of development.

We consider sustainable development as a change in system states that keep its integrity and maintain it within boundary limits of stability for a long period of time. It happens on the basis of forming a new structure of a system with adaptation to environmental pressure: population growth and limited resources. The stated above conflict trends are external demonstration of the pressure.

Thus, we have the following description of the global (the world economy) system development.

3 Development and Self-organization of the World Economy System

According to already defined criteria, the historical period, that is being studied, concerns development of the world economy system for over the period from 1825 till 2035.

Basing both on the periods when indicated systems of international monetary relations are functioning and on the quantitative characteristics we define the time limits when three states of the world economy system exist in the process of its development. In other words we determine the time periods as to three cycles and six periods of development of "the world economy" system. [Figure 1]

These time limits are represented as follows:

The first state

The first cycle of the world economy system development is the period when the gold standard system functions: 1825 – 1875 – 1895.

1. **The first period in the first cycle** of "the world economy" system development:

- the period from 1825 till 1875. Transformational period. The period of forming the gold standard system;
- the period when the bifurcation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 1.5%.

2. **The second period in the first cycle** of "the world economy" system development:

- the period from 1875 to 1895. The period of active functioning of the gold standard system;
- the period when the adaptation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 2.6%.

The second state
The second cycle of "the world economy" system development is the period when the Bretton Woods system functions – 1895–1945–1965.

1. **The third period in the second cycle** of the world economy system development:

- the period from 1895 till 1945. Transformational period of forming the Bretton Woods system;
- the period when the bifurcation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 1.8%.

2. **The fourth period in the second cycle** of development:

- the period from 1945 till 1965. Active functioning of the Bretton Woods system;
- the period when the adaptation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 5%.

The third state
The third cycle of "the world economy" system development is the period of Jamaican system – 1965 – 2015 – 2035.

1. **The fifth period in the third cycle** of "the world economy" system development is the period of transforming the system of international monetary relations and forming its new structure;

- the period from 1965 till 2015;
- the period when the bifurcation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 3.4%.

2. **The sixth period in the third cycle** of the world economy system development is the period which can be forecast, the period of active functioning of a new system of the international monetary relations:

- the period from 2015 – 2035 (predicted);
- the period when the adaptation mechanism of development is functioning;
- the rate of the world economy growth corresponds to 8 – 9% (predicted).

Table 1.

States of the world economy system	Time intervals	Periods of functioning	Structural characteristic of the state	Mechanisms of implementation	Quantitative characteristic. Development rates in percentage
The first state	1825-1895	the Ist 1825-1875	Functioning of the Gold Standard system of international monetary relations	Bifurcation	1,5
		the IInd 1875-1895		Adaptation	2,6-3
The second state	1895-1965	the IIIrd 1895-1945	Functioning of the Bretton Woods system of international monetary relations	Bifurcation	1,8
		the IVth 1945-1965		Adaptation	5
The third state	1965-2035	the Vth 1965-2015	Functioning of the Jamaican system of international monetary relations	Bifurcation	3,4
		the VIth 2015-2035		Adaptation	forecast 8-9

Basing on the system states outlined above we form the model of self-organization and development of the world economy. (Figure 1)

4 Sustainable Development of the Global Civilization – Non-linear Dynamic System

Above-stated model of development and self-organization of the global system (the world economy) allows us to make the following conclusions about properties of the model under research.

Two contrary processes that initially come to be the natural quality of the system itself lie in the base of system development. These processes are: the process of producing goods in conditions of limited resources and the process of their consumption in conditions of its unlimited growth.

The factor that produces dynamics is population growth for a long period of time.

The natural property of the system – dissipation of resources – is expressed by unlimited consumption of goods in conditions of limited resources for their consumption; it also predetermines the necessity of independent forming the system structure in order to provide efficient resource allocation for production and goods for

consumption, i.e. self-organization. The natural property of the system – non-equilibrium – is also caused by two contrary trends.

All hierarchic types of the social system have the property of production and consumption, for example, a country, a regional, civilized system and a global civilization. We can see the fractal symmetry of the main properties of the social system "the global civilization".

The system development happens by cycles with the interval of about 70 years. Every cycle of development goes through a conflict stage (50 years) and a non-conflict stage (20 years). They are implemented through the bifurcation and the adaptation mechanisms of development correspondingly. Old system relations are being restructured and new relations are being formed at the stage when the bifurcation mechanism of development works. This process is followed by decreasing quantitative indicator of development.

Whereas at the stage of the adaptation mechanism the development occurs without conflicts and is followed by uneven growth of quantitative indicator. Every cycle of development corresponds to one system state. Every consecutive state of the system possesses more complex structure and from the economic viewpoint it is more effective than the previous one: it provides the system integrity in conditions of the environmental pressure. Stability has its borders within which sustainable development occurs. When the system leaves the limits of stability it stimulates states of extremely non-equilibrium kind. It also leads to further indefinite behavior of the system where the global conflict can happen or self-destruction of the humankind can be one of the possible versions of development.

Therefore the main condition for keeping the system integral consists in maintaining stability of the system "the global civilization". The main objective of studying non-linear dynamic system behavior – development of the global civilization on the basis of modeling and conducting numerical experiments – is to calculate the stability limit as well as the conditions for maintaining the system within the estimated borders.

We can also see the complication of the system structure: self-organization in the form of the mechanism that implements sustainable development on the basis of spontaneous complication of the system structure.

We can make the conclusion that "the global civilization" system has properties peculiar to non-linear dynamics. The system can function in two different modes – bifurcation and adaptation converting from one functioning mode to another one in the developmental process. The system has the property of self-organization as well. The main function of the system lies in the development through which its aim (to maintain the integrity) is implemented.

The processes of production and consumption are regarded as the main properties of the system that generates development.

The fact that the system is maintained in limits of sustainable development through the process of development helps to keep the system integrity.

5 Formalization of the Global Civilization System Development

The global civilization system is regarded as global economic environment where countries and their group organizations are ordinary agents. Every agent has the same

properties as the system: they can be open, non-equilibrium, dissipative, self-organizing; they can also have the aim – to maintain integrity through the main function (development). Development is caused by contrary processes – the process of production and the process of consumption and is implemented through two types of the development mechanism: the bifurcation mechanism and the adaptation mechanism.

We can watch the fractal symmetry of all general properties ranging from the global system to its ordinary agent.

Development, the main function of the system, is viewed as the movement of economic environment. Basing on the assumption about maintaining boundary limits of system stability we solve the task of stable movement of environment and sustainable development of the global civilization in the context of fixed main properties and system characteristics.

At the first stage we study behavior and properties of an abstract non-linear dynamic system on the basis of reduction and fractal symmetry of the main properties. At the second stage we model and examine the behavior of specific system "the global civilization".

6 Modeling of Development of the System "Global Civilization"

On the basis of outlined properties we make a mathematical model of non-linear dynamic system – development of the global civilization, where:

- phase changes – ordinary agents, having the property of production and consumption
- space to which they belong to – phase space or global economic environment
- the main function is development expressed by movement of global economic environment

Thus, we make a non-linear system of differential equations that describe the main properties of an object where an equation of environmental movement will be the system solution. Then basing on numerical experiment we examine the properties of an equation of environmental movement.

7 Objectives of Simulation Modeling

1. To get some idea as to qualities and properties of attractors in the given system of both modes of functioning which the system forms in the development process. Attractors are mathematical images of determined modes of functioning. Change of modes – switch of functioning from an ordinary to a chaotic (bifurcation) mode shows the change of quantity and character of attractors. In "the global civilization" system attractors are supranational institutions that determine rules of behavior for system agents. These attractors also decrease indefinite trajectory of development which helps to maintain system stability in a mathematical sense of description. Thus we receive a mathematical concept of institutions necessary for maintaining sustainable development of global civilization system.
2. To make a numerical calculation of borders of stable environmental movement within which the global civilization system develops.

3. To get some idea about the character of change in number and in properties of system attractors for maintaining boundary limits of sustainable development of the global civilization system.
4. To show interaction of sustainable development, self-organization and available boundary value of the stability of the system under study.
5. To show evolution of the structure of an abstract social system under research.
6. To show evolution and to make a forecast of the structure of international monetary and financial relations of the global civilization.
7. To show evolution of the structure and to make a forecast of forming the main political institutions of the global civilization system in the XXIst century

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