Sustainable economic development: the main principles and the basic equation.

Dmitry CHISTILIN PhD

Dnipropetrovs'k University for Economics and Low
Department of International Economy and Economic Theory
Naberezhnaya Lenina str., 18, Dnipropetrovs'k, Ukraine, 49000
E-mail: unid@a-teleport.com

Abstract. This work offers system and information content of the following economic categories: development, sustainable economic development. The author has formulated the fundamental principles of sustainable development: the principle of minimum resource dissipation and the equation of self-organization, the law of conserving the economic potential of a social system. The basic equation of development has been formulated. The model of sustainable development is viewed on the basis of the equation.

Key words: Economic system sustainable development; Economic System self-organization, model sustainable development of the economic system,

1) Introduction

Scientists' interest in problem of economic development increased in the second part of the XX century when there arose a sharp contrast between developed countries of "the golden milliards" and the third world countries which were defined as developing countries or countries with developing economy. The contrast in the level of income among countries of the world community determined scientists' interest in analyzing conditions for nation welfare as well as in maintaining these conditions for highest possible period of time. The necessity of such analysis predetermined using the mathematic modeling of the economic growth. The first significant result was the combined model of Harrod-Domar based on changes of the main economic parameter which influences economic growth – the rate of investments. With increase in understanding influence of human capital, technologies and population upsurge on economic growth, the task of optimal economic growth was developed in the form of Solow and Solow-Swan's model with the function of Cobb-Douglas to be used. The growth of technologies and the population upsurge are also introduced into the model. These factors influence the main parameter of economic growth – fixed capital per worker, which defines efficiency of labour that is the economy growth rate.

Later there appeared models of economic growth by Ramsey, Braun, P. Romer, the models of technological changes, the model of Uzawa-Lucas with two sectors,

Schumpeter models of endogenous growth. With the help of these models scientists studied factors that influenced economic growth, among these factors were human and physical capital, technological changes, diffusion of technologies, migration and population upsurge, environmental pollution. Besides, an American economist W.Rostow studied conditions for sustainable growth of long duration. The works by S. Kuznets became the base for further development in understanding sustainable economic growth. According to Simon Kuznets, sustainable economic growth is a process of increase in productivity of national economy which has to exceed the population upsurge for the highest possible period of time. Thus, efforts of economic theory in the XXth century were directed at analyzing conditions that provide long-run economic growth. Then the concept claiming that economic growth lies in necessity of maintaining equilibrium state of economy with economic methods during the highest possible period of time was formed.

Almost all these approaches being expressed by mathematic models of economic growth did not find their qualitative application in economies of developing countries and later in the second part of 80-90es of the XXth century they did not find an application in analysis of economic behavior of countries with transitive economies.

There were approaches towards forming models of economic development including those which take into account structural changes in economy. For example, Arthour Lewis's model with two sectors; later this model was expanded and formalized by J. Fti and G. Ranis, the model of H. Chenery and others.

Being based on the experience of countries with developed economies, these models and theories connected with them turned to analysis into developing economies of the third world countries.

Further the elaboration of sustainable development theory reached the basic formal assertion widely accepted in the world as a category that is follow: "Sustainable development is the development that serves needs of today's generations and does not place possibilities for their usage by future generations under the threat" (WCED, 1987).

Correspondingly, the basic category of sustainability has the following formulation: "Sustainability is putting technical, scientific, ecological and economic social resources in order so that the resulting system can be maintained in an equilibrium state for some time and in space" (WCED, 1987).

The work of G. Brundland's committee resulted in categories stated above.

Thus, "sustainable economic development" and "sustainability" categories came from the environment of analysis into conditions for optimal economic growth basing on the postulate which necessitates exceeding the growth of national production against population upsurge. However, today there is no well-founded answer to the question: "Why have these models not given the practical result in countries with developing and transitive economy?" What do the existing models of economic growth not take into account?" Why are the existing models of development inadequate for changes occurring in many kinds of economies in the world?

2) The system of approach to the theory of sustainable economic development

It is obvious that the reason why existing models of economic development are inadequate for actual changes in economic life consists in approach towards understanding the concept of the following categories: “development”, “sustainability” and “sustainable development”. There is a need for accurate understanding the content of these categories; understanding should be based on adequate mathematic apparatus from natural sciences.

The analysis shows that models of economic growth as well as development models based on this approach do not function during long periods of time in economies of countries with an unstable (transitive) political system. Institutions of implementation of economic policy strategies that are based on applying existing models of economic growth are missing. This fact causes all attempts to create qualitative economic changes in society during all periods of time to fail.

In accordance with N. Kontradiev and Schumpeter’s approaches contemporary scientific theory has a great number of works on models of cyclic economic growth. Owing to these works we can clearly see time limit of classic and neoclassic models of economic growth; these models describe only one stage in a cyclic development – equilibrium or the stage of economic growth.

Models of cyclic development are not a substantial instrument for analyzing the process of economic development either.

The general theory of systems and the information theory provide other approach to qualitative understanding of the phenomenon of economic development.

Development is considered as the process of accumulating structural information that increases the level of system organization.

The general system theory holds development as the change of system states during a long period of time. Every state of a system is characterized by structural and quantitative characteristic.

Thus, in the process of system development there is a change of structural and quantitative characteristic. It shows the evolution of the system structure that adapts the latter to environmental impact. In economic system environmental pressure lies in population development and in limit of natural resources. The adaptation of the system takes place due to accumulating structural information, which raises sustainability on the basis of increase in the quantity of system organization.

Materials covered above testify the following conclusion: the model of economic development should contain the parameter that would characterize the structure of economic system in the sense of conditions and interaction regulations of economic agents among themselves. Numerical solutions of this model should show the evolution of this structure, which provides sustainability of a social system during a long period of time in the sense of its integrity. The political structure serves as a structure for a social system.

Thus, the category of “sustainability” takes a new content. The theory on sustainability which originates from works by Puankare and Lyapunova has a rule to answer two key questions:

– What exactly do we investigate for sustainability?

– Sustainability concerning what or in a sense of what do we investigate?

From all abovementioned information in the context of system-information understanding of sustainable development of social system we can claim that:

1. We investigate the process of social system development for sustainability; this system consists of political and social subsystems where the political system is the structural characteristic whereas the economic system gives the quantitative indicators of its states.
2. We investigate sustainability in the sense of maintaining integrity of the social system during a long period of time with regard to population development in the condition of limited resources.
3. The sustainable development of a social system is the consecutive, periodical change of its states during a long period of time, directed at increase in system sustainability (in a sense of maintaining its integrity) on the basis of restructuring its relations – evolution of a system structure. In a mathematical sense we can give more strict definition as to sustainability of social development that is based on availability of undetermined behavior in a social system.
4. The sustainable development of a social system is a consecutive change of states where all possible trajectories of its development are attracted to the area of sustainable positions in a phase space. The area is defined by the set of attractors characterizing the treatment of system functioning for a given period of time.

4.1 The set and the structure of attractors are defined by the quality and the type of a political structure.

4.2. The sustainable development of a social system is the movement of economic environment where solution to the system non-linear differential equation, describing it in the form of equation of economic environment movement, is sustainable against impact of managing parameter.

3) Self-organization of social systems

As we know the concept self-organization came to social sciences from physics, after the phenomenon chaos was discovered through the works by G. Haken, I. Prigojin and other scientists.

In natural sciences self-organization independently complicates the structure in conditions of strong instability of environment with the aim to maintain its sustainability against impact of environmental factors. Self-organization is peculiar to objects of inanimate and animate nature.

In case of social systems self-organization has a few levels:

The first level is a microlevel – the level where economic agents compete among themselves for limited resources and wealth; it results in optimizing their market distribution.

The second level is a macrolevel – the level where rules of economic game among agents concerning resource allocation and wealth distribution based on political subsystems as an optimal macroeconomic policy are formed independently. It maintains optimal resource allocation and wealth distribution among economic agents during a long period of time.

The third level is a metalevel – the level where the political structure and institutions of a social system are restructuring independently; we can witness it in the countries with transitive economy and we call it the process of transformation.

Correspondingly first two mechanisms of self-organization are implemented within sustainable functioning of a system. The third mechanism appears when the integrity of a system is under threat that is sustainability exceeded its boundary values.

Thus, the constant optimization of resource allocation and wealth distribution among system agents is the base to maintain its integrity for a long period of time. It is implemented through independent actions of economic system agents; actions are based on regulations laid down in a political structure that is through developing and implementing macroeconomic policy.

4) Correlation between self-organization and social system development

The process of forming and implementing optimal macroeconomic policy as well as its flexible correction in case of inaccuracy is the process of accumulating structural information for a long period of time. It connects with the fact that system being based on feedback laid down in a political structure receives the information about its current state. This forms the managerial decision by way of macroeconomic policy.

We can witness the evident fact about interrelation between self-organization and social system development as well as connection between level of self-organization and sustainability of system in the sense of its capacity to optimize macroeconomic policy and to react to economic and social destructive changes.

Self-organization is the mechanism of social system development where the quality of political structure defines possibilities of social system concerning sustainable development in the sense of transfer from crisis to economic growth without conflicts.

5) Principles of self-organization and sustainable development

There are two laws playing a defining role for sustainable development aimed at maintaining integrity of a system in conditions of population surge:

1. Principles of minimum dissipation of system resources are formulated as follows: "Every subsequent state of a system dissipates less resource than the previous one. In economic sense in every subsequent state resources are allocated in more optimal way than in the previous state; it expends economic effect, compensating increase in environmental impact." The principle of minimization of dissipation or scattering minimization that is optimization of resource allocation for production and distribution of goods for consumption naturally decreases resource dissipation. In other words the process of optimizing or implementing the principle of minimization of dissipation has a reverse direction concerning resource dissipation – production output (Y). The counteracting force F as for dissipating of system resources called as the principle of minimization of resource dissipation opposes to

economic growth or rate of production output $Y^{/}$ with the coefficient k that reflects structural qualities of the system – its institutions (political system) to produce useful work concerning optimization of resource allocation for producing goods to be consumed as well as reaction rate of the political system towards unfavorable economic changes in the form of structure adjustments in the current macroeconomic policy and changes of its direction in case of fallacy by non-conflict way through changing party in power to opposition. Putting it in other words, it is force that reflects the value of self-organization of the social system S. It can be recorded as:

$$S = -Y^{/} K_S \qquad \textbf{(1)}$$

the sign «-» means opposition of effect of force that compensates dissipation where S – the quantity of self-organization;

Y'- economic growth;

K_S – structural coefficient reflecting usefulness of the political system structure as for producing economic effect when optimizing resource allocation for production and goods for consumption.

2. The law of conservation of system economic potential.
   2.1. Economic potential – system ability to produce economic effect.
   2.2. Social system transferring from one system into another in the process of social and economic development maintains economic potential unchangeable.

It means the following:

When in the process of economic growth social system transfers from one state into another one it maintains the ability to produce economic effect and to create economic effect necessary and sufficient in order to maintain system sustainable in terms of preserving its integrity.

Economic potential of the social system is the ability to execute the work as for producing economic effect; this ability is produced by the system transferring from one state into others, which provides system integrity or sustainability of economic development process.

Economic potential is the potential ability of the economic system to execute the work as for producing economic effect when transferring from one state into another one in the process of economic development necessary and sufficient in order to guarantee system integrity or sustainable development in conditions of increasing population and scarcity of limited resources.

$$P_{(E1)} = P_{(E2)} = const \qquad \textbf{(2)}$$

Interrelation between sustainable development and self-organization can be seen in the figure 1.

6) Mathematic formalization of sustainable development.

Economic effect indicates efficiency or sustainability of development and can be formulated in the following way: $Y''/L''\geq 1$.

Potential of creating economic efficiency consists in ability to maintain productivity (efficiency) of a system at which the condition $Y''/L''\geq 1=const$ is to be implemented. This condition also characterizes the sustainable development.

Economic efficiency as a dynamic characteristic of development is the sustainable (constant) excess of growth rates of GDP over growth rate of population in a social system. Accordingly, to maintain system sustainability means maintaining its potential of creating economic effect $Y''/L''\geq 1=const$.

7) Sustainable development of the Economy: system approach

The author of this paper in the monograph "Self-organization of the World Economy: Euro-Asian Aspect" formulated the concept of development and self-organization of a social system and made the corresponding model. The model represents the main characteristics of the system itself and its development. The model is represented in the 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 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 states of the economy system in the process of its development. The structural characteristic for every state is the Political structure of the system.

The rate of GDP growth can be called the quantitative characteristic.

Every state of the system corresponds to 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.

8) Formalization of the system development

The economy system is regarded as economic environment where economic agents 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 system 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 the economy system.

9) The basic equation of the economy system development.

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

- phase variables – ordinary agents that has a property to dissipate resources in the form of production and consumption expressed by rate of production output $Y^{/}$ and its index – economic efficiency E_y and property of optimizing resources for production and goods for consumption expressed by value of self-organization S and its index K_S – structural coefficient of self-organization;
- space they belong to is the phase space or economic environment;
- the main function is the development expressed by economic environment traffic. Thus, ordinary agents of the system can be described by two phase variables (E_y, K_S), correspondingly phase economic space they belong to is recorded as $F = F(E_Y, K_S, t)$

where E_y - economic efficiency – **qualitative characteristics** of development, parameter that characterizes system capacity – ability to produce economic efficiency and dissipativity;

K_S – coefficient of self-organization – **structural characteristics**, parameter that reflects economic usefulness of system structure and characterizes minimization of dissipation or ability to optimize resource allocation for production and goods for consumption;

t – time

Development of the system global socium is recorded in the form of environment traffic equation like Burgers

$$\frac{dY^{/}}{dt} + Y^{/}\frac{dY^{/}}{dL_Q} = K_S\frac{d^2Y^{/}}{dL_Q^2} \qquad \textbf{(3)}$$

where: t – time interval during which system is investigated

Y – production output during time interval under analysis (estimated in GDP)

$Y^{/} = \frac{dY}{dt}$ - rate of production output or economic growth during time interval under analysis (for further record of equitation we take $Y^{/} = G$ (growth))

$Y^{//} = \frac{d^2Y}{dt^2}$ - rates of economic growth of a system during time interval under analysis.

$L_Q = LK_N$ – skilled labour or population growth during time interval under analysis taking into account qualification, where

L – population during time interval under analysis

L′ - speed of population growth

L″ - rate of population growth during time interval under analysis

N – population with higher education during time interval under analysis

K_N – coefficient of qualification of work in a social system. The coefficient characterizes the growth of structural information expressed by new knowledge. Creation of new knowledge is an intellectual work of population with higher education expressed by increase in population with higher education N. Thus,

$$K_N = \frac{dN}{dt} = N'$$

The quality of dissipation of resources is expressed by derived function $Y = F(k,L)$, where k – capital, L – labour resource. During long time intervals $t \to \infty$ $k \to 0$. We will write the derived function $Y = F(L,t)$ for long time interval. We also view the production function as resource consuming – dissipation. The property of optimizing resource allocation for production is expressed by the function of self-organization $S = F(I,t)$, where I – created information $I = F(N)$, t – time of creation and its introduction into the system. Information is the function of intellectual work of people with higher education defined by N. Thus, $S = F(N,t)$ is described with the equation $S = Y'K_S$.

Quantity of self-organization $S = Y^{/}K_S$ – counteracting force F as for dissipating of system resources called as the principle of minimization of resource dissipation opposes to economic growth or rate of production output Y' with the

coefficient $K_S = S / Y^{/}$ that reflects structural qualities of the system – its institutions (political system) to produce useful work concerning optimization of resource allocation for producing goods to be consumed as well as reaction rate of the political system towards unfavorable economic changes in the form of structure adjustments in the current macroeconomic policy and changes of its direction in case of fallacy by non-conflict way. In other words, it is force that reflects the value of self-organization of the social system **S**.

10) The analysis of equation shows that

1. The basis of equation consists in N. Kondratiev's hypothesis which says that cumulative accumulation of three components of a social system underlies the process of development (trend):
   - population growth *L*
   - capital accumulation *k*, together they make up the production function *Y = F(k,L)*
   - scientific-and-technological advance.

   In our case for a long time interval *k→0*, and scientific-and-technological advance is described with accumulation of new values (of information) or the function of accumulating people with higher education *I = F(N,t)*. Thus, the equation shows the convective transport of the main properties of the environment in space on the basis of the population growth taking into account the accumulation of new knowledge (information) influencing increase in productivity or dissipation of system resources. It is recorded as $\frac{dY^I}{dt} + \frac{dL_Q}{dt}\frac{dY^I}{dL_Q}$ or the total derivative from - $\frac{dY^I}{dt}$

2. Equation contains nonlinear term $Y^{/}\frac{dY^{/}}{dL_Q}$ since qualification of ordinary agent's work is the factor that originates nonlinearity proceeding from the simple consideration $Y^{/} = Y^{/}(L_Q)$. Nonlinear term shows the system property – dissipation, and reflects the accumulation of structural information in time and also dependence between rate of production output and change of population qualification along with change in its number. This term reflects the influence of structural information accumulation over the rate of production output.

3. Equation contains adhesive term $K_S\frac{d^2Y^{/}}{dL_Q^2}$, which reflects the system ability to resist resources dissipation or implement the principle of minimum dissipation of

system resources that is to optimize their distribution on the basis of current structure.

4. Thus, the left part of the equation shows the dissipative process – the rates of dissipating resources in time taking into account the growth of work qualification K_N, the right part shows the compensatory process – optimization of resources for production and goods for consumption k_S. The equation expresses the law of conserving the potential of the derivative of the economic effect which is formulated in the following way:
   - rates of dissipating unrenewed system resources during long period of time are compensated by their optimization on the basis of implementing the principle of minimum dissipation. It provides its integrity and implementation of the target function –maintaining homeostasis. Decrease in creating economic effect in the left part of the equation on the basis of decrease in the ratio of production output to population growth rate is compensated by creating economic effect on the basis of increase in the level of system organization in the right part of the equation.

5. The equation shows the evolution of structure. The accumulation of information $K_N = \frac{dN}{dt}$ which increases the rates of resource dissipation is compensated by its introducing into the system – structuring. In the right part of the equation we can see how the information becomes structural by changing k_S and increases the level of system organization. Basing on the action of the political system the information becomes structural in the form of laws put into force. The change of k_S from 0 to 1 shows accumulation of the structural information, complication or evolution of the system structure during long time interval.

6. Equation shows the evolution of structure, which enables us to make forecast of the future state of the system.

7. Sustainable decision of this equation will be a shock wave owing to competition between two opposite tendencies: dissipation and attenuation – minimum dissipation.

   7.1. Equation formally describes the wave nature of economic cycles.

11) The model of economy system development

The model is recorded in the following way:

$$\frac{dY^I}{dt} + \frac{dL_Q}{dt}\,\frac{dY^I}{dL_Q} = K_S \frac{d^2Y}{dL_Q^2} \qquad \textbf{(4)}$$

The condition of sustainability Y″/L″≥1.

The managing system parameter – economic efficiency E_Y. Equation is examined by stability of decisions depending on value of managing parameter. It is necessary to determine what value of the managing parameter should have so that solution of equation could be stable. It is also necessary to designate what geometrical image of obtained solutions of equations will be equal to stable states. To get a numerical result we create the algorithm, program and carry out numerical experiment.

References:

1. Abdeev,F. (1994). The philosophy of the information civilization. Vlados. Moscow.
2. Bogdanov A. (1989).Tectology. General organizational sciences . Economika. Moscow. V.1-V.3.
3. Kondratiev, N. (1989). The fundamental problems of the economic static and dynamic . Economika. Moscow.
4. Prigogin, I. Stengers, I. (1986). Order out of chaos. Progress . Moscow.
5. Schumpeter, J. (1982). The theory of an economic development. Progress. Moscow.
6. Chistilin D. K. Self-organization of the World Economy: Euro-Asian Aspect. -M., «Economika», 2004, 2006.
7. Malinetskiy G. G., Potapov A. B. Modern Problems of Non-linear Dynamics. -M., URSS, 2002.
8. Chulichkov A. I. Mathematical Models of Non-linear Dynamics. –M., Physmatlit, 2003.
9. Blank M.L. Stability and localization in chaotic dynamics. – Moscow, MZNMO, 2001.
10. Malkin I.G. Theory of movement stability. – Moscow, Science, 1966.
11. Foley K. Duncan, Michl R. Thomas. Growth and Distribution. – London, Harvard University Press, 1999.
12. Filatov A. N. Theory of stability. – Moscow-Izhevsk, 2003.
13. Intriligator M. Mathematical methods of optimization and economic theory. – Moscow, Iris Press, 2002.
14. Daly Herman E. Ecological Economics and Sustainable Development. Selected essays of Herman Daly. – Northhampton, USA, Edward Elgar Publishing, 2007.
15. Arestis Ph., McCombie J., Vickerman R. Growth and Economic Development. Essays in Honour of A. P. Thirlwall. - Northhampton, USA, Edward Elgar Publishing, 2006.
16. Barro Robert J., Sala-i-Martin X. Economic growth. Second edition. – London, The MIT Press, 2004.
17. Aghion Ph., Howitt P. Endogenous Growth Theory. - London, The MIT Press, 1998.
18. Todaro Michael P. Economic Development. – Moscow, Unity, 1997.
19. A.Ryzhenkov Models of cyclical growth.- Novosibirsk, 2003.