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SWITCHOVER MODE OF REPRODUCTION AND THE PROBLEM OF COORDINATION[1]

The proposed version of macroeconomic theory of capital reproduction is related to thethesis that the dynamics of the economy are caused by the change in generations of capital and there is a problem of coordination between these generations. This paper discusses the so-called "switchover mode of reproduction". As shown by the mathematical model, a coordinated growth is possible when the social and economic interests are agreed between the labor and the capital, as well as under a monetary policy that stimulates such growth. An uncoordinated growth poses a threat of economic crisis.

Keywords: capital, circulation, reproduction, fixed capital, money, depreciation, switchover mode of reproduction, coordination, model

The discussions on the condition and prospects of economic science, especially its macroeconomic field, have been under way for many years. Their latest escalation was related to the global financial and economic crisis of 2008–2009, when limitations of the Dynamic Stochastic General Equilibrium (DSGE),the most popular tool of modern macroeconomic analysis, and of its underlying principle of representative agent became apparent. A number of articles have been published claiming that the new Keynesian DSGE models reflect mathematically beautiful but artificial virtual world, which has almost no relation to reality [1, 2]. There were calls for revision of fundamental theoretical models [3] and even complete replacement of the methodological foundations of theorizing in economics [4].

In our opinion, one of the drawbacks of macroeconomic growth theories is that they are abstracted from a number of substantial fundamental processes that underpin the economic growth. In particular, all known macroeconomic models do not consider the fact that the process of economic growth occurs against the backdrop of change in generations of fixed capital and that this change necessarily takes place through the circulation of capital. Instead, the fixed capital is presented as a kind of substance, which declines and expands by a certain value on an annual basis and, in case of growth, acts as a driver for GDP growth[2]. The fact that fixed capital has an age structure and its reproduction is accompanied by expenditure and accumulation of money capital is sidestepped by the designers of growth models.

It is interesting to note that Karl Marx, who is so stubbornly rejected by modern theorists, did partly manage to accomplish something that fail to do these theorists when designing a scheme for the simple reproduction of capital at the level of Subdivisions I and II of public production. He considered the age structure of fixed capital and captured the phenomenon of the circulation of money capital. This resulted in a very important theoretical point: the money spent by owners of worn (old) fixed capital of Subdivision II on purchasing the new fixed capital in the current year should be equal (in case of simple reproduction) to the money accumulated in the same year by the owners of existing fixed capital of Subdivision II

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[2] For example, in simple DSGE models, the process of fixed capital accumulation is described only by a well-known equation $K_{t+1} = (1 - \delta)K_t + I_t$, where $0 < q < 1$ is the depreciation rate. (See, for example, A. Zaretsky (2012) Methodology for Designing, Resolving and Assessing the Parameters of DSGE models. Minsk. Working Paper of IPM Research Center, WP/12/05, p. 4, in Russian).

for the purpose of future purchases of new fixed capital. Karl Marx has rightly called this equation "the law of reproduction in an unchanged scale" [5, p. 550].

We consider such state of affairs in the theory of growth as unacceptable and associate with it the inability of macroeconomic science to predict the impending crises. In a series of studies carried out in 2010–2014, we proposed a new version of macroeconomic theory of reproduction, which, in our opinion, is sensitive to the crisis and potentially (with appropriate adaptation to real statistics) can predict the emergence of crises [6–8]. In this paper, we will first briefly describe the economic substance of the new version of the theory of reproduction. Then we will focus on the problem of sensitivity which a mathematical model, that is adequate to the new version, can demonstrate to the crisis phenomena. For this purpose, we will consider the cases of coordinated and uncoordinated development of an economy that is obeying to switchover modes of reproduction.

Let's consider the macroeconomic level (real sector) as Nof simultaneously operating macroeconomic subsystems $G = \{G_1, G_2, \ldots, G_N\}$, each of which is different from other subsystems by its age of fixed capital estimated, for example, as of the beginning of the current year (here G_1 is the youngest subsystem, G_N is the oldest subsystem). Our first task is to show that, under certain assumptions, the specified set of macroeconomic subsystems can operate in accordance with the rules of so-called "switchover mode of reproduction", and this mode, in turn, is impossible without the circulation of money capital. Let's formulate three assumptions.

Assumption No. 1: Let's assume that N, the number of macroeconomic subsystems simultaneously operating in the current year $(t_0; t_1)$ in the real sector of the economy, is equal to T_f, which is the average life expectancy of fixed capital of the real economy rounded to the nearest integer. Let's assume the value of T_f to be the same for all subsystems. This assumption allows us to abstract from the real spread in life expectancies of individual elements (types) of fixed capital, which, in our opinion, can be done when analyzing the behavior of macroeconomic subsystems. And when we take into account that, in the existing macroeconomic models, the age structure is not considered at all, then our assumption is a step towards the concretization. In addition, this assumption allows us to put in order the set of subsystems $G = \{G_1, G_2, \ldots, G_N\}$ in such a way that each subsystem G_{i+1} will be exactly one year older than the subsystem G_i.

Assumption No. 2: Let's assume that, just as the real sector of economy corresponds to "household" sector, in our theoretical analysis, each macroeconomic subsystem G_i will correspond to its own household $\boldsymbol{HH_i}$. For their labor, the workers of i-th household receive money income (wages and other benefits) from i-th subsystem. Let's also assume that the capital of each macroeconomic subsystem belongs to some owner (it does not matter whether it is private, corporate, or socialist). The owner seeks to preserve and increase its capital.

Assumption No. 3: As it is known, with the households, the real sector of economy produces nonproductive goods (we call this type of activity the program ***B***) and reproduces its fixed capital (the program ***A***). We assume that each macroeconomic subsystem can do the same. That is, it represents, so to speak, the small macro-economy,which can implement both program ***A*** and program ***B***. Let's also assume that the time T_v required to implement the program ***A*** (reproduction of the fixed capital) is the same for all subsystems from the set $G = \{G_1, G_2, \ldots, G_N\}$ and is equal to one year. It is obvious that $T_v << T_f$. In this case, the difference $(T_f - T_v)$ represents the time that can be spent by any macroeconomic subsystem on program ***B*** within the entire life of its fixed capital.

And now let's consider the particular aspects of operation of subsystems $G = \{G_1, G_2, \ldots, G_N\}$ that meets these three assumptions in the current year $(t_0; t_1)$. At the beginning of this year, the age of fixed capital for the youngest subsystem G_1 is 0 years, while the age of the oldest subsystem G_N is (T_{f-1}) years. At the end of the year $(t_0; t_1)$, all subsystems will become one year older. In this case, the fixed capital of oldest subsystem will reach T_f, that is the critical age, beyond which the probability of accidents and stoppages due to physical wear increases dramatically and, therefore, exacerbates the need to renew the fixed capital.

To avoid catastrophic consequences, the oldest subsystem G_N must, during the calendar year $(t_0; t_1)$, reproduce for itself the new fixed capital so that it can, by the beginning of the year $(t_1; t_2)$, implement the procedure for replacing the old fixed capital by the new fixed capital. Since the time T_v is assumed to be equal to one year, then during the year $(t_0; t_1)$, the old subsystem will not implement the program ***B***. Instead, it will completely focus on implementing the program ***A***. Other, younger subsystems $\{G_1, G_2, \ldots, G_{N-1}\}$ do not have to worry in the year $(t_0; t_1)$ about the operability of their fixed capital. In this year, such subsystems may be involved only in the implementation of the program ***B*** and ignore the tasks of self-reproduction of the fixed capital (program ***A***).

By the beginning of next year, the subsystem G_N will be rejuvenated and will switchover from program A to program B. Instead of it, the implementation of program A will be carried out by the subsystem G_{N-1}, which by that time will have grown older. And so on. This is the switchover mode of reproduction.

Such mode is not discussed in the economic literature. There is another prevailing view — the real sector of the economy, which is a macroeconomic entity, produces, on an annual basis, both the new fixed capital (program ***A***) and consumer goods (program ***B***). That is,there is a joint implementation of two programs by a single macroeconomic system, in other words, a joint mode of reproduction. We agree with this view, but we believe that it is not in contradiction with the switchover mode. Indeed, if the set of subsystems $\{G_1, G_2, ..., G_N\}$ is combined into a single entity, it would look as if the sum of subsystems is engaged in the joint mode of reproduction on an annual basis. That is, at the macroeconomic level, the switchover mode would disappear from the view of researcher. It would become "invisible", even though it really exists at the level of macroeconomic subsystems.

A key feature of switchover mode is that its operation cannot proceed without the involvement of money capital. Indeed, while an individual subsystem is involved in implementing the program ***A***, it sells nothing on the side and, therefore, does not receive from outside any monetary proceeds to pay taxes, rent, and most importantly, the wages to the workers involved in implementing the program ***A***. Therefore, such subsystem must either accumulate the necessary money capital in advance, or raise the capital on the side (loan, etc.), or do the both. In particular, in the year $(t_0; t_1)$, we can observe, on the one hand, the accumulation of money capital (depreciation, etc.) in subsystems $\{G_1, ..., G_{N-1}\}$, which in the current year implement the program ***B***. On the other hand, we can observe the expenditure of money capital in subsystem G_N, which has the oldest fixed capital but, at the same time, did manage to accumulate, prior to the year $(t_0; t_1)$,the money capital sufficient to finance in the current year $(t_0; t_1)$the investment program ***A***.

It is established [8, p. 145–146] that, in the developed banking system, the money capital spent in the year $(t_0; t_1)$ by subsystem G_N on paying the labor of the workers in the household $\boldsymbol{HH}_N$ transforms within the same year into the accumulation of the money capital of subsystems $\{G_1, G_2, ..., G_{N-1}\}$. That is, the economy is experiencing the circulation of this capital.

Moreover, along with this circulation, there is one more circulation, which is the circulation of working money capital between subsystems $\{G_1, G_2, ..., G_{N-1}\}$ and households $\boldsymbol{HH}_1, \boldsymbol{HH}_2, ..., \boldsymbol{HH}_{N-1}$. Its essence is that the workers of these households, on a monthly basis, receive from subsystems $\{G_1, G_2, ..., G_{N-1}\}$ the remuneration for their labor and, on a monthly basis, return this remuneration in the same subsystems by using it to buy the consumer goods.

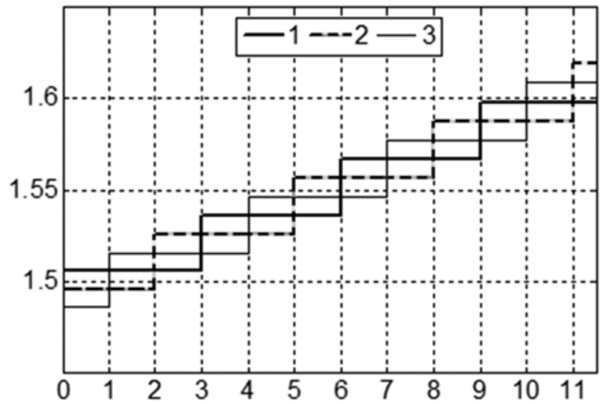
Therefore, the flow of money in the economy can be represented by two types of circulations. In this sense, it is similar to the process of blood circulation in the human body. But if the particular aspects of the latter have been identified in the 18th century, the economic science, including the Chicago School of monetarists, still does not have sufficient understanding of this "two-round" feature of monetary circulation.

In the previous papers [7, 8], we built a basic mathematical model that simulates both the switchover mode of reproduction and "two-round" monetary circulation. In this model,the dynamics of manufactured product, fixed capital, as well as the monetary funds of macroeconomic subsystems and households, are described by the expressions for their change rate (the increment amounts of these assets per time unit) by using the differential equations.

We will not provide in this paper the description of basic model but will restrict ourselves to comments on its capabilities. The key is that this model is designed to build the trajectories for the future growth of products, as well as the fixed capital and money capital of subsystems $\{G_1, G_2, ..., G_N\}$ depending on various assumptions on the upcoming money issue, planned growth of labor remuneration for implementing the programs ***A*** and ***B***, expected nature of innovative activities in subsystems, etc. By forming these trajectories, the model can demonstrate that in some situations the economy consisting of subsystems $\{G_1, G_2, ..., G_N\}$ may be running the threat of crisis phenomena and even economic cataclysms, while in other situations, on the contrary, the development may be possible without any crisis.

Let's introduce two definitions. Let's assume that the economy is in the mode of coordinated development, if its parameters are agreed so that the base model generates the trajectories of crisis-free (non-cyclic) growth and does not signal the threat of economic collapse[1]. If these con-

[1] We agree with Giovanni Dosi who believes that the issue of primary importance for modeling the behavior of complex evolving systems is not the search for balanced solutions but the problem of coordinating the elements of such systems which can be achieved only dynamically [9].



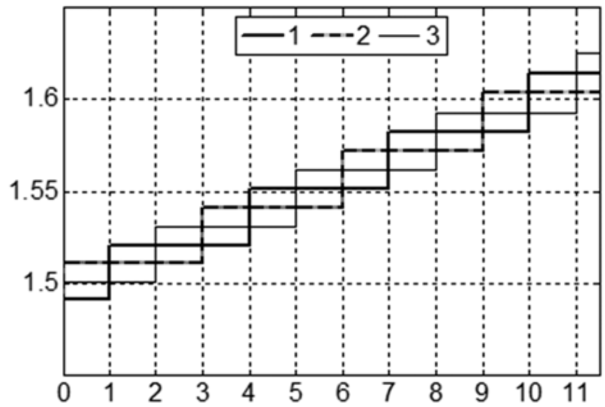


Fig. 1. *Dynamics of the product Yi(left chart) andfixed capital Ki (right chart) at N = 3 in the situation of coordinated growth(the horizontal axis represents time in years, the values in the vertical axis are expressed in conventional monetary units)*

ditions are not met, then the economy is in the mode of uncoordinated growth.

As the experimental calculations show, the coordinated development (without the crisis) of the economy that includes subsystems $\{G_1, G_2, ..., G_N\}$ and households $\boldsymbol{HH}_1, \boldsymbol{HH}_2, ..., \boldsymbol{HH}_N$ is possible in case the following are equal to each other:

I — growth rate of payments for the labor of households when implementing the program ***A***;

II — growth rate of payments for the labor of households when implementing the program ***B***;

III — growth rate of production of consumer goods;

IV — growth rate of money issue.

A sign of coordinated development is that, under these conditions, the subsystems do not scatter from each other. Below is an example, when the economy includes three subsystems, the products and fixed capitals of which are woven into a "pigtail" and grow exponentially (Fig. 1)[1].

A coordinated development of the economy shown in Fig. 1 represents the ideal scenario for the development of the economy that includes three subsystems ($N = 3$). It is ideal because strict observance of equations I–IV on the long time interval is possible only in an exceptional case. In fact, the ratio of labor payment rates for implementing programs ***A*** and ***B*** (equations I–II) is changing over time and depends on how active are trade unions in defending the interests of producers of investment and consumer products, as well as on a number of other factors. Similarly varied is the ratio of growth rates of consumer goods and those of the money issue (equations III–IV). It depends on the ability of monetary authorities to anticipate the rate of production of consumer goods, take into account the degree of deficit (or surplus) of liquidity at the beginning of the calculation period, etc. However, this ideal scenario is useful as a point of reference to be pursued in order to avoid the economic crisis or mitigate its impact.

Fig. 1 also shows that, when complying with equations I–IV, each of the three subsystems periodically either comes ahead of the other two subsystems in terms of output and fixed capital increase, or lags behind them ("pigtail"). This situation is repeated each time when the subsystem renews its fixed capital on the basis of innovation and thereby obtains a temporary advantage. In our view, such "coordination in dynamics" resembles the competitive game of Red Queen, where in the apt words of Lewis Carroll, "it takes all the running you can do, to keep in the same place." According to some economists, this game represents one of the fields in the evolutionary theory. It describes well the problem of arms race and competition in the area of high technology [10].

Now, let's demonstrate a case of uncoordinated development. For this purpose, we will violate the condition III. Namely, let us assume that, in the economy that includes three subsystems, one macroeconomic subsystem provides higher growth rates of production compared with other subsystems as a result of effective activities of its managers, engineers and workers. Let's also assume that this advantage is maintained over a long time. The calculations show that in such situation the economy starts to spin out of control: it activates a positive feedback mechanism leading to the loss of coordination of its key parameters and, in the end, to destabilizing the economy in general (Fig. 2).

Fig. 2 indicates the process of growing self-destruction of the economy. In real life, the cases of such loss of coordination exist and are often accompanied by severe political conflicts that arise because the households engaged in the developing part of the economy have to support the live-

[1] All charts in this paper are based on calculations in accordance with the model. These calculations have been authored by A. Rubinstein.

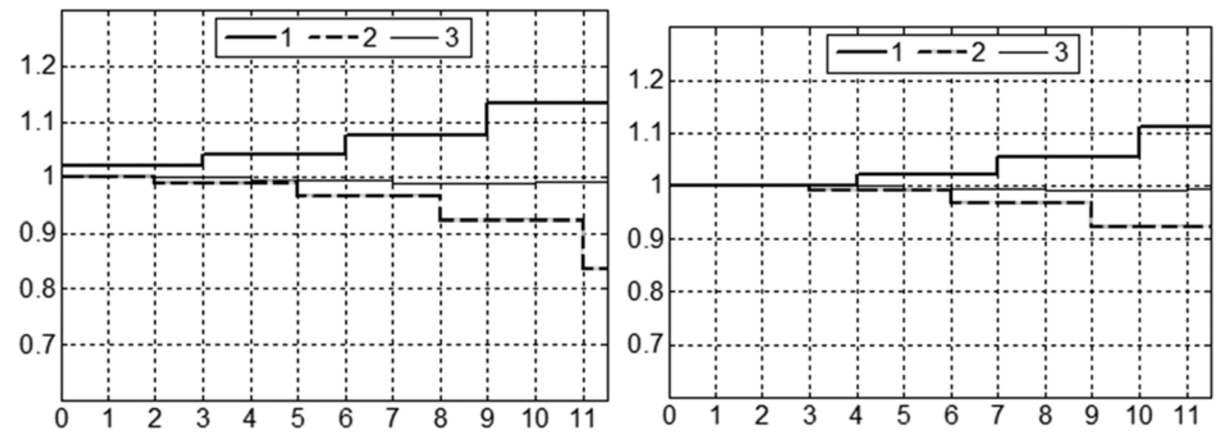


Fig. 2. *The dynamics of product Y_i (left chart) andfixed capital K_i (right chart) at N = 3, the case of loss of coordination(the horizontal axis represents time in years, the values in the vertical axis are expressed in conventional monetary units)*

lihood of households in the degrading part of the economy. For example, industrial Catalonia insists on secession from Spain, a highly technological Lombardy looks for a way to separate from Italy, and oil-rich Scotland wants to exit UK.

Let's consider another example when the phenomenon of loss of coordination does not remain in place for a long time but represents a short-term shock. We will introduce in the basic model the assumption that the economy is strictly adhering to equations I–IV in the period from year 0 to year 36 and moves along a trajectory of coordinated growth. The equations I and II are violated from year 37 through year 41: The payments to households exceed by 12 % the level that meets the coordinated growth trajectory. Starting from year 42, the economy returns to strict compliance with equations I–IV (Fig. 3).

Fig. 3 describes the emergence of economic crisis and overcoming it by returning the economy to parameters of coordinated development (to equations I–IV). The figure also shows that the process of overcoming the crisis may take the form of a demographic echo.

So far, we have considered the instances of coordinated and uncoordinated development of the economy in terms of the behavior exhibited by the trajectories of the product and fixed capital of individual subsystems. If these trajectories scatter, the economic development becomes uncoordinated, if they are weaved into a "pigtail", the economy is in coordinated development mode. However, the behavior of trajectories of the product and fixed capital reflects only one, material side of coordination and uncoordination. There is also another, monetary side, which relates to behavior of trajectories of money capital that ensures the financing of production of fixed capital, as well as the financing of trajectories of households' funds spent on acquiring the consumer goods.

By using the base model, we will try to establish, in which instances the trajectories of money capital that ensures the reproduction of fixed capital (let's designate this capital as M_Y) are coordinated and do not lead to economic crises, and in which instances, on the contrary, they are uncoordinated. For this purpose, let's add to equations I–IV the equation V, in which gi is the growth rate of

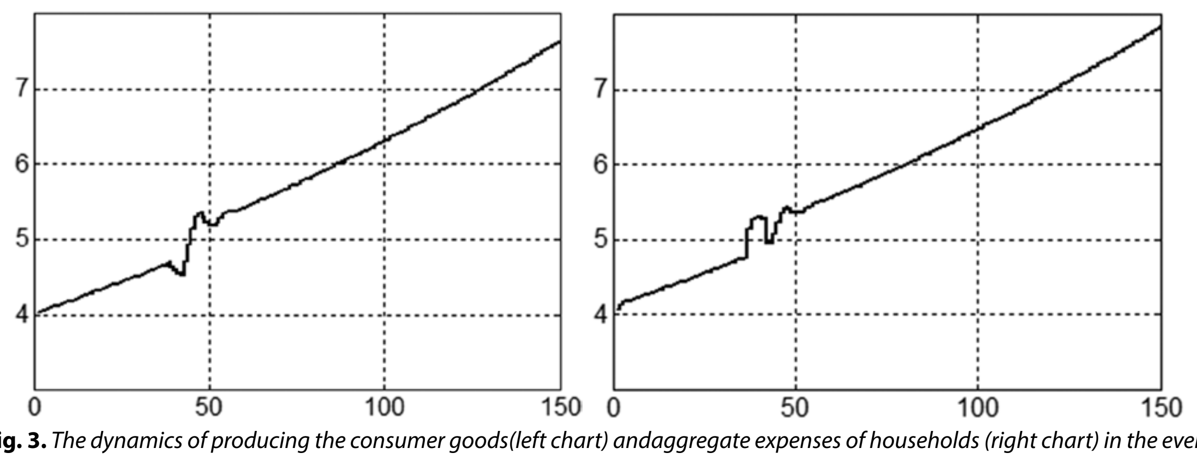


Fig. 3. *The dynamics of producing the consumer goods(left chart) andaggregate expenses of households (right chart) in the event of temporary shock(the horizontal axis represents time in years, the values in the vertical axis are expressed in conventional monetary units)*

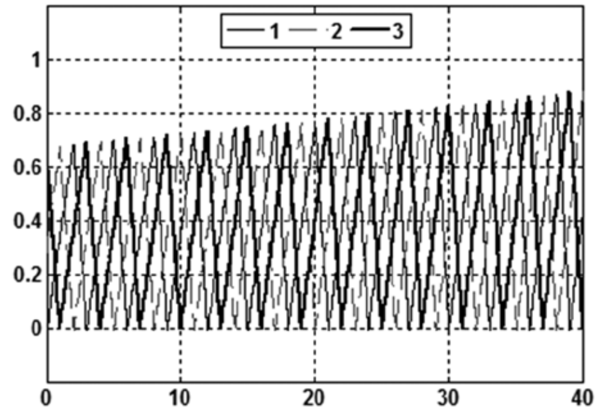


Fig. 4. *Gross accumulations M_Y at N = 3 (the horizontal axis represents time in years, the values in the vertical axis M_Y in conventional monetary units)*

production of the product created by *i*-th subsystem and depends from DK'_i/K'_i, the growth rate of fixed capital of the same subsystem, and from k_g, the investment efficiency factor:

$$g_i = k_g \left(1 + \frac{\Delta K'_i}{K'_i}\right), \qquad \text{(V)}$$

where k_g may be both greater or smaller, or equal to one.

Fig. 4 describes the dynamics of M_Y in case $k_g = 1$.

Fig. 4 indicates that the money capital of each subsystem is accumulated on a periodical basis, and then spent on financing the reproduction of fixed capital (program ***A***). Moreover, it is spent entirely, as evidenced by tangency between the trajectories M_Y in the horizontal axis. The latter means that, in the economy, there are no excesses of M_Y capital underutilization or, on the contrary, indicates its lack for implementing the program ***A***. In this sense, the development of the economy can be viewed as coordinated in its monetary aspect. Let's also note that the trajectories of product and fixed capital calculated with the base model at $k_g = 1$ and equations I–IV are woven into a "pigtail" in the same way as shown in Fig. 1. That is, the monetary coordination is supplemented by material coordination.

Now, we will consider the dynamics M_Y in instances when $k_g > 1$ and $k_g < 1$. The results of calculations in accordance with the base model are presented in the form of four scenarios (Fig. 5–8)[1].

All four scenarios of M_Y dynamics differ from dynamics shown in Fig. 4. The Fig. 5, where $k_g = 0.98$ during only five years (in years 50–54, in other years $k_g = 1$) shows that the money capital M_Y rises

[1] In the following figures, the horizontal axis represents time in years, while in the vertical axis the values M_Y are expressed in conventional monetary units. The number of macro-economic subsystems is 3.

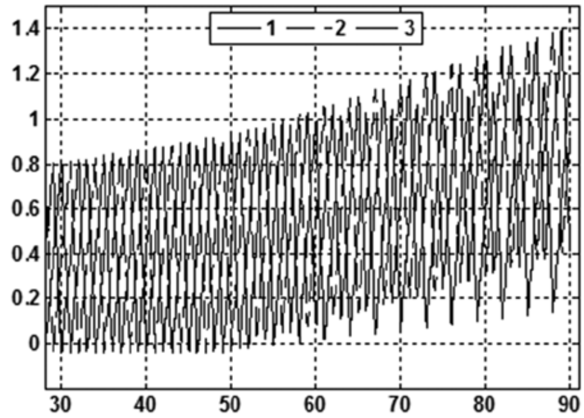


Fig. 5. *k_g = 0.98 during years 50–54*

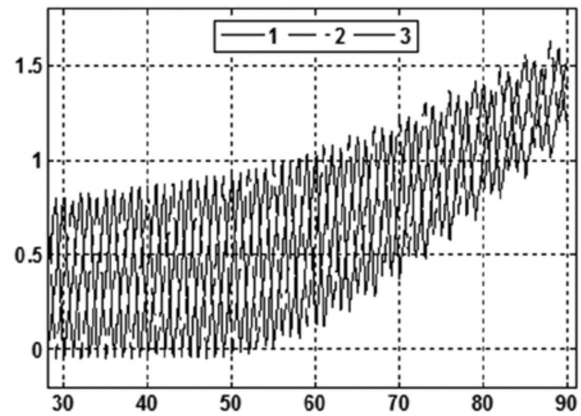


Fig. 6. *k_g = 0.98 during years 50–150*

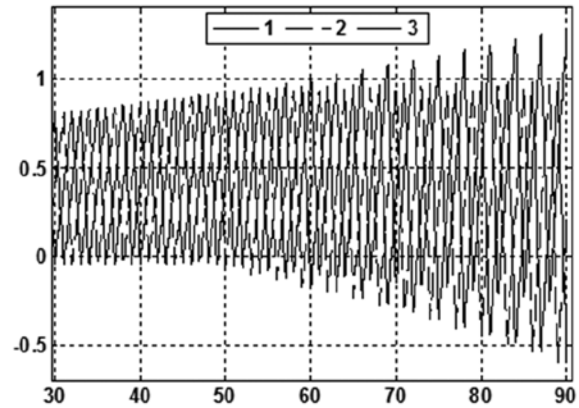


Fig. 7. *k_g = 1.02 during years 50–54*

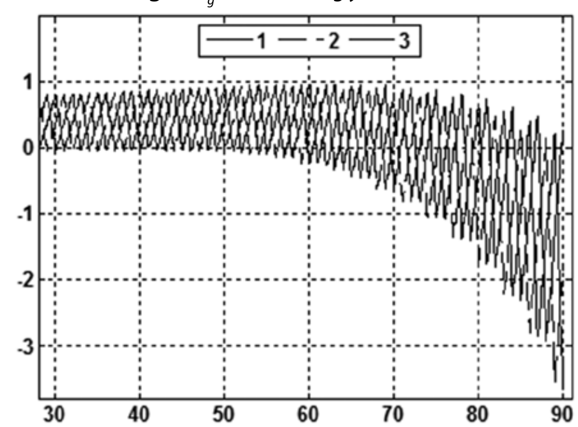


Fig. 8. *k_g = 1.02 during years 50–150*

Table

Values of kgin the USA in 1970–2009*

Years	k_g	Years	k_g	Years	k_g	Years	k_g
1970	0.97	1980	0.96	1990	1.01	2000	0.99
1971	0.98	1981	1.02	1991	1.01	2001	0.97
1972	1.00	1982	0.99	1992	1.02	2002	0.98
1973	0.98	1983	1.05	1993	1.00	2003	0.99
1974	0.92	1984	1.05	1994	1.00	2004	0.96
1975	1.00	1985	1.02	1995	1.00	2005	0.96
1976	1.01	1986	1.00	1996	1.01	2006	0.99
1977	0.97	1987	1.00	1997	1.01	2007	1.02
1978	0.99	1988	1.02	1998	1.00	2008	1.00
1979	0.96	1989	1.01	1999	0.99	2009	1.01

* Calculations based on data from: The 2012 Statistical Abstract — US. Table 667, 781.

above the horizontal axis. This means that part of gross accumulations is underutilized. Moreover, the underutilization grows over time, despite the fact that, from the year 55, $k_g = 1$. The underutilization increases especially quickly when $k_g = 0.98$ at the time interval of years 50–150 (Fig. 6).

The opposite situation is observed in case when $k_g = 1.02$ (Fig. 7, 8). Here, the money capital dips under the horizontal axis to negative values. We interpret this behavior as the evidence that subsystems are unable to accumulate, on their own, the money capital M_Y for the reproduction of fixed capital of the same subsystems. Negative M_Y is the borrowed capital. The Fig. 8 shows that subsystems do not repay this loan.

As we can see, all four scenarios of M_Y dynamics pose a threat of economic crisis. The excess money in case when $k_g = 0.98$ (Fig. 5, 6) will put pressure on the market and cause the demand to exceed the offer. Of course, the subsystems can get rid of excess money by shifting it to the stock market, but then the demand for securities will start to rise dramatically. There will be speculative expectations, and this market could collapse following a financial bubble. The subsystems can do otherwise by increasing their bank deposits with excess money, but if the banks are not able to place their additional funds, the borrowing costs will go down. This may create crisis of excess liquidity.

When $k_g = 1.02$ (Fig. 7, 8),the threat of crisis stems from the high probability of credit defaults that compels to hike the interest rates. If subsystems attempt to obtain the necessary funds in the stock market through an increasingly expanding issue of securities, this may lead to the fall of stock prices. Since the banks are actively using the asset securitization, such fall threatens to provoke the collapse of banking system.

Thus, the calculations made in accordance with the model show that a prolonged deviation of macroeconomic subsystems $\{G_1, G_2, \ldots, G_N\}$ from complying with the condition $k_g = 1$ creates an uncoordination in the economy that may lead to economic crisis. Such deviations exist in real life. According to US statistics, in 1970–2009, k_g has been periodically staying at the level either greater or smaller than one. Only in some years, it was strictly equal to 1 (see table). It is possible that these real fluctuations ofkg are indeed (as indicated by our base model) the cause of worsening deficit/excess of liquidity, increased panic buying in the stock market or, on the contrary, a steep fall in demand, etc.

We intend to test these correlations in the near future. At the same time, we will continue to further improve the base model that simulates the switchover mode of reproduction. In the meantime, referring to the point made at beginning of this paper, we would like to stress that, unlike the models of DSGE type, our base model does not hide the phenomena of uncoordination behind the price equilibrium but, on the contrary, uncovers them and, therefore, provides a warning about the possibility of economic crisis.

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