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Modeling of the Financial System Using the Concept of Vacuum Polarization

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***Abstract*—The possibility of using the theory of deterministic chaos is considered. Vacuum polarization is a fundamental type of physical processes. The average value of any physical quantity must remain zero. Taking this assumption as a fundamental law, we propose a model that describes the processes of variation (depreciation) of the value of money. At the same time, we consider the processes of variation of the initial amount of funds introduced into the economic system by an independent "generator" (for example, the US Federal Reserve System) in a situation when the amount of returned funds must exceed the amount of given credits. Since the amount of returned funds must exceed the amount borrowed by the value of the refinancing rate, either a constantly increasing debt is formed, or an increase in the money introduced to the economy. The relationship of the "depreciation" of money is also investigated in this model**

Keywords—cash, depreciation, financial system, model, regularities, trends.

I. Introduction

The existence of various macroeconomic schools: classicism, Keynesianism, monetarism, reflect, at a minimum, the complexity of the formation of a model of an economic system.

In different models, the role and patterns of monetary circulation are determined differently. In particular, the model of circulation of money and

inflation is formed in different ways. At different historical stages, these models turn out to be untenable.

Taking into account that the economic system represented as the social practice of people under the division of labour and the existence of property rights to the results of labour, aimed to satisfy the needs and based on the equivalence (determination of the equivalent) of exchange processes, money initially acts as an equivalent, and are essentially models of these processes.

It is logical to assume that socio-economic systems, as a part of the surrounding world, are subject to general objective physical laws. In particular, the fundamental type of physical processes - vacuum polarization - can serve as the basis for modelling monetary circulation in socio-economic systems.

The starting point of the work is the assumption that socio-economic systems, as a part of the surrounding world, obey the universal objective physical laws. In particular, the fundamental type of physical processes - vacuum polarization - can serve as the basis for modeling the properties of socio-economic systems.

In accordance with this type, the average value of any physical quantity must remain zero (constant, by changing the reference point may be reduced to zero).

This approach is well known in physics in various formulations, such as, for example, the law of conservation of matter, the law of conservation of energy [2,3].

The aim of this work is to develop a model of money circulation, using the concept of vacuum polarization: money is generated artificially as the equivalent of goods and services produced by the economy, and cyclically "returns" to the generator.

II. Materials and Methods

When modelling the economic system, the subject of research in this study is the patterns of change in the monetary equivalent of labour results and needs that are satisfied in the course of practical activity of people in market economy.

Research Methods - Mathematical Modelling.

Since at present time money circulation is determined by an independent participant (regulator) of economic systems (for example, the US Federal Reserve System), which credits all economic activity, funding money according to the conditions of returning of greater amount of money than taken on credit, by the value of the lending rate .

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In such a situation, to simulate the process of cash flow in the economy, taking into account the fundamental property of vacuum polarization, the following prerequisites (axioms) must be fulfilled:

1. The number of participants satisfying their needs is constant.
2. The amount of money given on credit is allocated at the beginning of the period and does not change over the period of one cycle (usually a year)
3. Money, as an exchange equivalent, is returned to an independent regulator.
4. The average price of economic transactions is defined as the quotient of the division of cash volume in the economy, divided by the number of participants in the economic system.
5. Since the economy does not have additional physically existing funds needed to repay the cost of the loan, they are taken as a new loan in the next step.

III. Results

It is quite obvious that the model describes the properties of a dynamic system that may be described in phase space [4], [5] with the help of a system of differential equations:

$$\frac{d\boldsymbol{X}}{dt} = \boldsymbol{F}(\boldsymbol{x}) \tag{1}$$

In our case it is a discrete system:

$$\frac{x}{t} = F(x) \tag{2}$$

where Δx is the change in x over a period of time Δt.

At a formalized level, the model is as follows:

Oi - the amount of money contributed to the economy in the form of a loan (for example, the Fed printed $ 1,000,000 for i = 1 first period)

Sti - lending rate (for example, 10% for i = 1 period)

WPi - received proceeds from the sale for i -th period (must be equal to the amount of money received from the Regulator)

Koli - the number of participants on the i-th period.

Cenai is the price of purchased goods and services for the i-th period reduced to one participant. Price is determined by the ratio:

$$Cena_i = \frac{O_i}{Kol_i} \tag{3}$$

Dolgi - creditors debt not secured by cash available in the economy on the i-th period

Infli - the absolute value of the "depreciation" of money (relative to the first period) on the i-th period:

$$Infl_i = \frac{\left(\frac{WP_i\ (1+St_i)}{Kol_i}\right)}{Cena_1} \quad 1 \tag{4}$$

$Year_{ihf}$ is the depreciation value relative to the previous period:

$$Year_{ihf} = Infl_i \quad Infl_{i-1} \tag{5}$$

For i> 1

Then the solution of equation (2) can be obtained in tabular form, using the EXCEL processor.

A fragment of the calculation is shown in Fig. 1.

Period	O	Em	St	WP	Cena	Kol	Dolg	Infl	Year_ihf		
0	1000000	=Dolg	0,1	=O	=WP/Kol	100000	=O*(1+St)-WP	=(WP*(1+St)/Kol)/$F$2-1	0		temp
1	=B2+C2	=Dolg	0,1	=O	=WP/Kol	=G2*(1+temp)	=O*(1+St)-WP	=(WP*(1+St)/Kol)/$F$2-1	=I3-I2		0,1
2	=B3+C3	=Dolg	0,1	=O	=WP/Kol	=G3*(1+temp)	=O*(1+St)-WP	=(WP*(1+St)/Kol)/$F$2-1	=I4-I3		
3	=B4+C4	=Dolg	0,1	=O	=WP/Kol	=G4*(1+temp)	=O*(1+St)-WP	=(WP*(1+St)/Kol)/$F$2-1	=I5-I4		
4	=B5+C5	=Dolg	0,1	=O	=WP/Kol	=G5*(1+temp)	=O*(1+St)-WP	=(WP*(1+St)/Kol)/$F$2-1	=I6-I5		

Fig. 1. Fragment of tabular model with calculation formulas

In the tabular model, the additional variable WPi is used to give a probability for further investigation of the influence of additional factors.

The variable "temp" allows to include an additional factor in the model - the share of the increment of system participants (market growth rate).

At the first stage the situation, when the market volume is assumed to be constant, lending is introduced "at one time" at the beginning of the period, loan repayment is carried out "at one time" - at the periods' end, is modeled.

To return the interest on the loan at the end of the period, additional funds are issued in the amount of the refinancing rate, which are given in the form of an increase of credit volumes.

Interest Rate does not change.

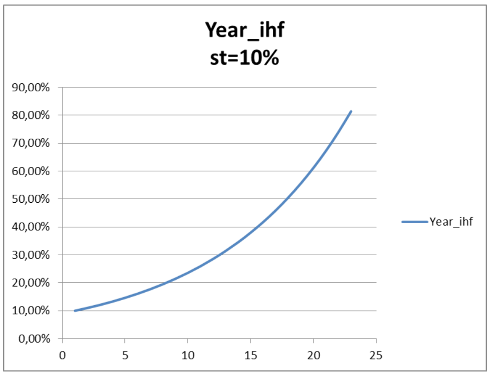
For example, with the initial amount of cash in the amount of $ 1,000,000 at 10% per annum for one year, introduced into the economic system where the number of participants is equal to 100,000, in one year it will be necessary to return to the Regulator $ 1,100,000, but only 1,000,000 is practically available. That is that during the next year it will be necessary to "reprint" (emmit) an additional $ 100,000 into the economy.

But one year later it will be necessary to return 1 121 000 $, etc.

The data fragment and the graph of "depreciation" of funds by periods is shown in Fig. 2.

Perio	O	Em	St	WP	Cena	Kol	Dolg	Infl	Year_ihf	
0	1000000	100000	10,00%	1000000	10	100000	100000	0,00%	0,00%	temp
1	1100000	110000	10,00%	1100000	11	100000	110000	10,00%	10,00%	0,00%
2	1210000	121000	10,00%	1210000	12,1	100000	121000	21,00%	11,00%	
3	1331000	133100	10,00%	1331000	13,3	100000	133100	33,10%	12,10%	
4	1464100	146410	10,00%	1464100	14,6	100000	146410	46,41%	13,31%	
5	1610510	161051	10,00%	1610510	16,1	100000	161051	61,05%	14,64%	
6	1771561	177156	10,00%	1771561	17,7	100000	177156	77,16%	16,11%	
7	1948717,1	194872	10,00%	1948717	19,5	100000	194872	94,87%	17,72%	
8	2143588,8	214359	10,00%	2143589	21,4	100000	214359	114,36%	19,49%	
9	2357947,7	235795	10,00%	2357948	23,6	100000	235795	135,79%	21,44%	
10	2593742,5	259374	10,00%	2593742	25,9	100000	259374	159,37%	23,58%	
11	2853116,7	285312	10,00%	2853117	28,5	100000	285312	185,31%	25,94%	
12	3138428,4	313843	10,00%	3138428	31,4	100000	313843	213,84%	28,53%	
13	3452271,2	345227	10,00%	3452271	34,5	100000	345227	245,23%	31,38%	
14	3797498,3	379750	10,00%	3797498	38	100000	379750	279,75%	34,52%	
15	4177248,2	417725	10,00%	4177248	41,8	100000	417725	317,72%	37,97%	
16	4594973	459497	10,00%	4594973	45,9	100000	459497	359,50%	41,77%	
17	5054470,3	505447	10,00%	5054470	50,5	100000	505447	405,45%	45,95%	
18	5559917,3	555992	10,00%	5559917	55,6	100000	555992	455,99%	50,54%	
19	6115909	611591	10,00%	6115909	61,2	100000	611591	511,59%	55,60%	
20	6727499,9	672750	10,00%	6727500	67,3	100000	672750	572,75%	61,16%	
21	7400249,9	740025	10,00%	7400250	74	100000	740025	640,02%	67,27%	
22	8140274,9	814027	10,00%	8140275	81,4	100000	814027	714,03%	74,00%	
23	8954302,4	895430	10,00%	8954302	89,5	100000	895430	795,43%	81,40%	

(a)

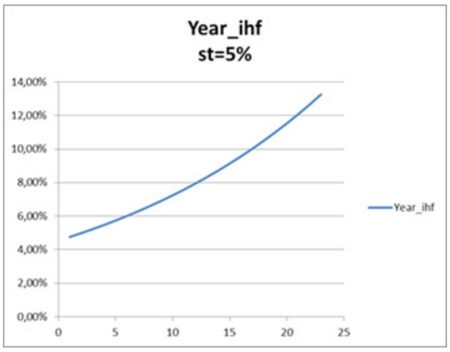


(b)

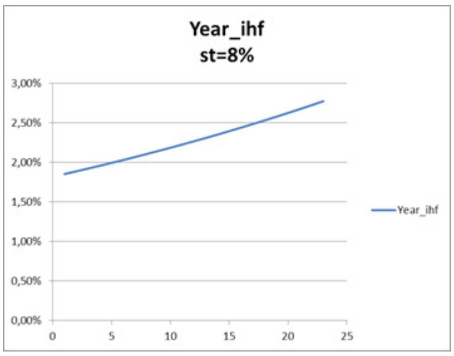
Fig. 2 Tabular model and schedule "depreciation"

Obvious is the conclusion about the increase in the rate of "depreciation" of funds, ahead of the refinancing rate.

If the number of participants in the economy increases (the model takes into account discrete - over the years - increase in the market) in an amount not exceeding the refinancing rate, the cash depreciation will decrease to zero. A number of graphs for the values of growth rates of 5% and 8% are shown in Fig.3.



(a)



(b)

Fig. 3 Schedule of "depreciation" for the market growth rate of 5% and 8%

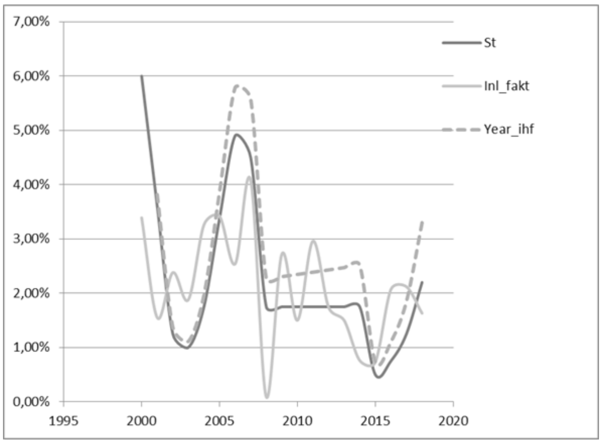
As we see, the rate of "depreciation" decreases from 80% up to 14 and 2.8, respectively.

Let's build a model of cash depreciation on the basis of statistical data on the Fed's refinancing rates and data on US inflation over the past 20 years [4], [5].

The simulation results are shown in Fig.4

Period	O	Em	St	WP	Cena	Kol	Dolg	Infl	Year_ihf	Inl_fakt
2000	1000000	60000	6,00%	1000000	10	100000	60000	0,25%	0,00%	3,39%
2001	1060000	38160	3,60%	1060000	10,6	100000	38160	6,00%	5,75%	1,55%
2002	1098160	13727	1,25%	1098160	10,9816	100000	13727	9,82%	3,82%	2,38%
2003	1111887	11118,87	1,00%	1111887	11,11887	100000	11118,87	11,19%	1,37%	1,88%
2004	1123006	19652,6	1,75%	1123006	11,23006	100000	19652,6	12,30%	1,11%	3,26%
2005	1142658	38621,86	3,38%	1142658	11,42658	100000	38621,86	14,27%	1,97%	3,42%
2006	1181280	57882,74	4,90%	1181280	11,8128	100000	57882,74	18,13%	3,86%	2,54%
2007	1239163	55762,34	4,50%	1239163	12,39163	100000	55762,34	23,92%	5,79%	4,08%
2008	1294925	22661,19	1,75%	1294925	12,94925	100000	22661,19	29,49%	5,58%	0,09%
2009	1317587	23057,77	1,75%	1317587	13,17587	100000	23057,77	31,76%	2,27%	2,72%
2010	1340644	23461,28	1,75%	1340644	13,40644	100000	23461,28	34,06%	2,31%	1,50%
2011	1364106	23871,85	1,75%	1364106	13,64106	100000	23871,85	36,41%	2,35%	2,96%
2012	1387977	24289,61	1,75%	1387977	13,87977	100000	24289,61	38,80%	2,39%	1,74%
2013	1412267	24714,67	1,75%	1412267	14,12267	100000	24714,67	41,23%	2,43%	1,50%
2014	1436982	25147,18	1,75%	1436982	14,36982	100000	25147,18	43,70%	2,47%	0,76%
2015	1462129	7310,645	0,50%	1462129	14,62129	100000	7310,645	46,21%	2,51%	0,73%
2016	1469440	11020,8	0,75%	1469440	14,6944	100000	11020,8	46,94%	0,73%	2,07%
2017	1480460	18505,75	1,25%	1480460	14,8046	100000	18505,75	48,05%	1,10%	2,12%
2018	1498966	32977,26	2,20%	1498966	14,98966	100000	32977,26	49,90%	1,85%	1,63%

(a)



(b)

Fig. 4. Simulation results with real Fed rates for the period 2000–2018.

The simulation results show the principal workability of the model, despite of the difference in the prerequisites - a real increase in total dollars (national debt) does not allow to accept as constant the volume of domestic market. However, modelling according to the US Federal Reserve for inflation and comparison with the limited market model shows comparable results in terms of trends, since the growth of the US market is due to the expense of other countries financed by the Fed, therefore the US market itself can be assumed as "limited".

IV. Confirmation

Correlation analysis of data on inflation and refinancing rates of the USA over the past 18 years allows us to estimate the existence of a linear relationship between sets of values of random variables.

Since the value of the refinancing rate and the inflation value for the simulated period may be considered as random variables, the analysis of the existence of a linear relationship between the real rate (Sti) and the value of the money depreciation Year_ihf was undertaken. The results of the analysis performed in EXCEL are shown in Fig. 5.

St	Inl_fakt
0,06	0,0339
0,036	0,0155
0,0125	0,0238
0,01	0,0188
0,0175	0,0326
0,0338	0,0342
0,049	0,0254
0,045	0,0408
0,0175	0,0009
0,0175	0,0272
0,0175	0,015
0,0175	0,0296
0,0175	0,0174
0,0175	0,015
0,0175	0,0076
0,005	0,0073
0,0075	0,0207
0,0125	0,0212
0,022	0,0163

Correlation			
r	0,53	Significance level	0,05
n	19	tкр	2,109816
|tr|	2,59		
Hypothesis testing			
Variables dependent?	True		

Fig. 5. Simulation results with

Comparing the values of t-statistics with a critical value allows us to state a linear relationship between the refinancing rate and the inflation rate based on official data [6], [7]

V. Conclusions

A currency circulation model based on the concept of vacuum polarization has been developed and implemented.

The study of the model confirms the existence of a link between “depreciation” and the value of the interest rate of the regulator’s lending.

The results of implementation of the model with real US FRS refinancing rates during 18 years showed a correlation between the Fed rate and the inflation rate, which allows us to make a conclusion that the model works in principle.

It is important to underline that this model can be used to study the effect on the “depreciation” of funds of other important factors, such as expansion and market contraction (change in the number of participants), withdrawal of funds from economy (decrease in the amount of funds)

It should be noted that the rate of inflation, calculated in a number of countries using different methods, may not correlate with the “depreciation” of money, caused by the principal parameter - the value of the refinancing rate.

References

[1] E. J. Dolan et al.. Money, banking and monetary policy / Per. with English. V. Lukashevich, etc.; under the General ed.- Moscow, -448.. 1996 Available: https://economy24info.com/kred-it-obraschenie-denejnoe/dengi-bankovskoe-delo-denejno-kredit-naya.html

[2] . S. P. Kuznetsov Dynamical chaos and hyperbolic attractors. From mathematics to physics — Moscow, Izhevsk: Regular and chaotic dynamics, Izhevsk Institute of computer research, 2013.- 488 c.— Available: http://www.iprbookshop.ru/28886.html

[3] M.B. Ignat’ev Kiberneticheskaja kartina mira. Slozhnye kiber-fizicheskie sistemy [Cybernetic picture of the world. Complex cyber-physical systems]. St. Petersburg, SUAI Publ; 2014. 472 p.

[4] M. B. Ignat’ev ; A. E. Karlik ; E. A. Iakovleva ; V. V. Platonov Linguo-Combinatorial Model for Diagnosing the State of Human Resources in the Digital Economy 2018 XVII Russian Scientific and Practical Conference on Planning and Teaching Engineering Staff for the Industrial and Economic Complex of the Region (PTES) https://ieeexplore.ieee.org/document/8604217

[5] D. A. Shustov. The possibilities of using the linguo-combinatorial approach in the modeling of economic processes. Information-Communication-Society (ICO–2019): Proceedings of the XVI all-Russian scientific conference / St. Petersburg, 24 – 25 January 2019.: Publishing house of Etu, 2019. - Vol. 1. P. 390-394

[6] Reference materials > inflation > US Inflation Rate Federal reserve: 2000 – 2019, http://global-finances.ru/stavka-frs-ssha, [Accessed March 27, 2019

[7] World Finance. Inflation in the US, https://fin-plus.ru/info/inflation_index/usa/, [Accessed March 27, 2019