Predictive-Free Methods for Digital Financial Asset Management and Delayed Functional-Differential Economic Game Models

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Abstract—The Federal Law dated 31.07.2020 N 259-FZ "On Digital Financial Assets, Digital Currency and on Amendments to Certain Legislative Acts of the Russian Federation" entered into force on January 1, 2021. The law defines the legal status and procedure for the circulation of cryptocurrencies. Given the increasing interest from investors, the specific nature and growth of the digital assets market, new effective management tools and methods are required, which are proposed in the paper.

The paper constructs two models of economic processes described by functional-differential equations, i.e. delayed equations generalizing the Verhulst equation. The first model represents the process in the model of an isolated economic center of forces functioning under external disturbing influences. The second model characterizes processes in two centers interacting through information and financial fields. Both models belong, in fact, to the class of open systems, systems interacting with the external environment. It is noted that they can be combined with the models developed within the analogy of economic and open thermodynamic systems. The analysis of uncertainty problems, the problems of uncertainty of laws of economics and parameters of models of processes, and the analysis of the ways to overcome them are given. The possibilities of the digital economy and the dangers associated with it are discussed.

Keywords—functional-differential equation, static model, dynamic model, economic center of power, digital economy, mathematical methods of economy, information technology, digital financial assets, block chain

I. INTRODUCTION

Managing decisions in the crypto currency market under uncertainty and risk requires hybrid approaches and methods combined for effective monitoring, forecasting and management [1]. The high risk and volatility of digital financial assets arise from the lack of regulation, the presence of reliable value exchange channels with fiat currencies, a high degree of speculative components, and ambiguous legislative interpretation in different countries and continents. In this case, the application of traditional asset management schemes and models in relation to cryptocurrencies becomes a difficult and inefficient solution. There is a need to create no-forecast management models as a mathematical basis for stable hedging risks and preserving the purchasing power of the asset in case of unpredictable hypervolatile bursts of value. The concept of such a system can be represented by the diagram in Fig. 1, which illustrates a combined digital financial asset management model.

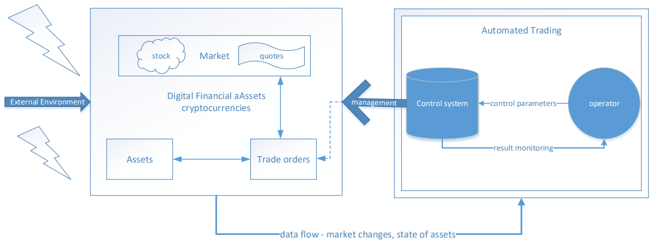

Fig. 1. Digital financial asset management model.

In the cryptocurrency sector in asset management, there can be predictive and non-predictive methods of decision-making. To implement the first approach, the analysis of time series [2] with preliminary smoothing, optimization and appeal to the methods of the surge theory and fuzzy systems are proposed. In the prediction-free methods, the control decisions are made according to the trend, which is realized on the basis of the developed algorithms. This guarantees increased stability of the system and reduces risk in uncertainty, but may require more time to complete trading cycles.

As an alternative or supplement to the no-forecast approach, a number of forecast models based on approximating polynomials, statistical evaluation, neural network forecasting of time series and technical-economic analysis [3] are offered.

II. FUNCTIONAL-DIFFERENTIAL PREDICTIVE MODELS OF ECONOMIC GAMES WITH LAGGING

The problem of uncertainty has always been a problem of economic science - a problem of modeling economic processes. This problem is determined by the very nature of the modeled object, which according to N.N. Moiseev is an organized community of thinking living beings [4] with all its interrelations, merits and demerits. In these conditions even an ideally adjusted model is difficult to use in practice because, as a rule, its parameters are not known. This was noted by both N.N. Moiseev and V. Leontiev [5, 6]. The authors of these works noted in this connection, in particular, that the most complete description of the capitalist form of production is given not by the modeling with uncertain parameters, but by Marx's "Capital". Another interesting pattern observed by J. Muth is that "all available information, which can increase the accuracy of price forecasts, is very quickly transformed into the current decisions of speculators". This pattern is cited in a review of the development of economic science [7].

The complexity of the problem of uncertainty in modern conditions seems to increase in connection with the development of digital technology [8], with the uncertainty of the rules of circulation, both traditional and digital currency; with the uncertainty of the rules of access to economic information and, naturally, with the possibility of uncontrolled influences on the processes taking place in the economy. The question arises as to the reliability of measures taken to combat computer crime, the growth of which has already been noted at the official level. In this case, the reference to the economic illiteracy of the victims is not justified by the heterogeneity of the population's interests, by virtue of the impossibility of demanding, for example, from a mathematician or physicist, knowledge of all the subtleties of possible mechanisms of deception. In principle, digital technology can free them from this obligation, allowing them to concentrate entirely on the tasks at hand. However, this is only theoretical.

There is also the danger of growing opportunities to manipulate economic processes on the part of influential groups of government officials, leading to a detachment of the economy from the scientific and technical needs of the state, to slow development and, even, to the suspension and collapse of the country's backbone industries, which has already taken place. We should also mention the emergence of new opportunities for the formation of financial pyramids and the withdrawal, possibly for benign purposes, of the accumulated surpluses from the population, which was previously practiced in the form of bonds.

According to the realized principles of functioning, models of economic development processes are divided into processes: static and dynamic, deterministic and stochastic, linear and nonlinear, continuous and discrete, optimal and playful. The discussion of the practical application of stochastic models is devoted to [9], modeling and interpretation of the economic consequences of catastrophic climate change is the topic of [10]. Modern economic growth theory and common mathematical models of economics are the topic of books [11, 12]. The theory and practice of economic models is a topic of work [13]. The ideas of differential game theory [14] apply in principle to game models of economics. Methods of time series analysis, stochastic approximation, recurrence estimation and decision making [15-17] also belong to the mathematical apparatus of economic analysis and modeling. Modeling of reversible and irreversible, closed and open economic and thermodynamic systems is covered in [18-24].

Economic games are essentially wars waged from the centers of power for power and influence, capital and prestige; wars in which there is no shame in spreading inaccurate information, irresponsibility and lies.

Such a state of social relations naturally increases both the uncertainty of factors of economic development and the uncertainty of the model; in some cases, there is a need to take into account new factors and, accordingly, to modify the model. At the same time, it is obvious that the causes of the uncertainty problem noted in [5, 6] remain valid under the new conditions. Despite the uncertainty, the modeling of economic processes is of undoubted interest both in terms of the analysis of the causes that generate them, in terms of their prediction at the stationarity intervals, and in terms of discovering the causes of abrupt changes in their dynamics.

This paper introduces into consideration the functional-differential equations modeling economic games in conditions of competing centers of power, when decisions are made on the prior (lagging) or unreliable information about the values of any economic factors, and in conditions of their considerable variability. Such a mechanism underlies, for example, many known fraudulent schemes. The upside-down game, which is the subject of Emile Zola's "Rugon-Macquarie" cycle, can be referred to the same type.

A. Model of growth in demand for a foundation product

Let us consider the problem of growth of demand for a product under the conditions of finite time of its production, cost and limited initial value of the fund. Similar problems, such as the population growth rate and the rate of production of products with saturation (parameter $x(t)$), are modeled in many cases by the Verhulst equation [12]:

$$\frac{dx(t)}{dt} = a\big(1 - bx(t)\big)x(t)$$

where a and $b-$ appropriate coefficients. However, here we do not take into account either the lag, which in the general case may have a distributed nature, or the costs of stimulating, for example, advertising costs, or the saturation of the market of this type of product.

Under these conditions, the price of the product in the first approximation can be represented by a system of equations of the general form

$$\frac{dP(t)}{dt} = a\big(1 - bP(t)f(J(t), M(t), \Phi(t))\big)P(t),$$

$$J(t) = \varphi\big(P(t), J(t), \Phi(t), M(t)\big),$$

$$M(t) = \psi\big(P(t), J(t), M(t)\big),$$

where $P(t)-$ the volume or flow of output, $J(t)-$ information, incentive support, $M(t)-$ the flow of consumption or market saturation, $\Phi(t)-$ fixed assets, $f(t)$, $\varphi(t)$ and $\psi(t)-$ accordingly selected functions.

The peculiarity of informational, stimulating support, consisting in the tendency to distort or delay information about the actual state of the economic system requires the transition to a functional-differential model in the general case with a distributed delay, within which the first of the above equations can be presented, for example, in the form of

$$\frac{dP(t)}{dt} = a\left(1 - b\left(P(t) + \int_{-h}^{0} P(t+\tau)dw(\tau)\right)f(J(t), \Phi(t), M(t))\right)P(t)$$

where $w(\tau)-$ is a non-negative weight function.

Of course, these equations are only the simplest model of the economic game, the model of enrichment or ruin of only one center of power. It does not explicitly model the mechanism of competition between representatives of different centers of power, does not reveal the interaction of competing subjects. The game in the framework of this model is reduced to a struggle for supremacy in the information field, the victory in which actually solves the problem of competition. In a similar way, for the same purpose - to displace the rival, victory can also be achieved by playing in the financial field.

The disadvantage of this model is that there is no explicit connection between the output of the same type of products by different centers of power. To eliminate this drawback we can, for example, introduce a model of competition between two centers of power, a model described by a system of differential equations with a lag:

$$\frac{dP_1(t)}{dt} = a\left(1 - b\left(P_1(t) + \int_{-h}^{0} P_1(t+\tau)dw(\tau)\right) f(J_1(t), \Phi_1(t), M_1(t))\right) P_1(t)$$

$$\frac{dP_2(t)}{dt} = a\left(1 - b\left(P_2(t) + \int_{-h}^{0} P_2(t+\tau)dw(\tau)\right) f(J_2(t), \Phi_2(t), M_2(t))\right) P_2(t)$$

$$J_1(t) = \varphi_1\left(P_2(t), J_2(\mathrm{t}), \Phi_2(t), M_2(t)\right),$$

$$J_2(t) = \varphi_2\left(P_1(t), J_1(\mathrm{t}), \Phi_1(t), M_1(t)\right),$$

$$M_1(t) = \psi_1\left(P_2(t), J_2(\mathrm{t}), \Phi_2(t), M_2(t)\right),$$

$$M_2(t) = \psi_2\left(P_1(t), J_1(\mathrm{t}), \Phi_1(t), M_1(t)\right),$$

where the lower indices 1 and 2 denote the variables and functions of the first and second centers of force, respectively.

It is not difficult to generalize the above model to the case of more centers of force if only to give the equations a vector-matrix form. However, in some cases this is not necessary due to the frequent consolidation of the interests of the centers of forces around two or three selected strongest centers. The functional dependences represented by the functions $f_k(t)$, $\varphi_k(t)$ and $\psi_k(t)$, depend on the peculiarities of the set tasks and goals, by virtue of which they can be described by different expressions.

A distinctive feature of the equations of this model, obtained by modifying the Verhulst equation to the form of equations with distributed delay, is the presence of many possible types of dynamics of the processes they form: from stationary state to relaxational and chaotic auto-oscillations, which is of some interest also in terms of representation of the dynamics of economic processes. The topic of investigation of processes within the framework of specific economic problems deserves a separate consideration.

III. Conclusion

Mathematical modeling of the dynamics of processes in the economy is of interest perhaps not so much for the purpose of long-term forecasting as for the purpose of identifying the conditions of critical situations and preparing for their elimination. Various algebraic conditions of resources production and consumption balance, models of employment and scientific and technological progress; economics-related tasks of demography and sociology, single-sector models of economy, tasks of growth and identification of stock markets and productions, tasks of forecasting growth of one or another resource are covered quite fully in the literature on economics. A separate place is occupied by the issues of security and control in the digital economy, which seem to play and will play, undoubtedly, a significant role in the future.

Dynamic models occupy a more modest place. Here simplified models are mostly used, allowing only a qualitative assessment of observed processes, but, nevertheless, making appropriate recommendations. As the model becomes more complex, as noted above, the parametric problem of uncertainty arises, which, in principle, is solvable within the framework of the identification problem.

In its essence, the economy is an open system - a system under constant influence of external factors of sociological, natural, environmental, demographic, industrial, scientific and technological and other types. To take into account the influence of all these factors on the economy, and even more so to predict, is not a theoretically feasible task. Nevertheless, this does not mean abandoning the study of complex economic processes, just as one does not abandon weather forecasting in conditions of its obvious unpredictability even for a relatively short period of time.

As an open system, the economy has many analogies with nonequilibrium thermodynamics, considered from this perspective in papers [18-24]. This way, based on the combination of the laws of thermodynamics and economics, of both static and dynamic type, with the algorithms of systems identification, seems to be the most promising today. The complex dynamics of the processes observed in the presented models of economics, in particular, in the form of relaxation oscillations, has been confirmed by unpublished results of modeling of this type of equations.

This study considers a number of predictive models [25, 26] based on approximating polynomials, statistical estimation, neural network forecasting of time series and technical-economic analysis. Applying the mentioned models and solutions in particular or in complex, it is possible to make adaptive adjustment of parameters of the automated cryptocurrency management system built on the forecast-free model. Depending on market conditions, volatility and risks, the priority of the proposed models allows to choose a more effective solution for different phases of the market.

The results of the technical and economic analysis performed as part of the study are shown in Fig. 2.

Fig. 2. Results of technical and economic analysis of bitcoin value prediction.

Based on the results of the technical and economic analysis in Fig. 2 (*The chart is not a trading recommendation*), it is possible to adapt the digital financial asset management system to the relevant market conditions. Follow the recommendations from the predictive models [25], the automated management system performs asset management through trade orders.

Thus, by supplementing the no-forecast approaches with forecasting tools, effective risk-controlled asset management of the digital economy becomes possible. The introduction of crypto-asset management systems and the reservation of a portfolio of highly liquid digital assets can increase the state's resilience to geopolitical and currency risks, as well as strengthen the sovereign wealth fund.

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