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SCIENCE AND TECHNOLOGY

Methods of Cognitive Analysis in Devising and Substantiating Strategies of Economic Development

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Abstract—The article presents a cognitive model for the support of decision-making in pursuing innovation economic policy with regard to the primary and agricultural sectors of the Russian economy. The methodological basis of the approach is the study of a directed graph representing the formalization of a cognitive scheme describing the interaction of many factors in a complex system of socio-economic relations at the level of the national economy. The results obtained by simulation modeling of five scenarios for the economic development of the Russian economy are discussed. The role of innovation and institutional changes and accomodative monetary policy in ensuring sustainable economic growth is shown.

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Cognitive economy as a new direction of the evolution economy. The dynamics in the main macroindicators indicate that for almost ten years the Russian economy has not shown any noticeable progress (Fig. 1). This long stagnation cannot be explained by extraneous circumstances, no matter how significant they are. This implies that the model underlying the Russian economy is no longer capable of securing its growth. Long-term stagnation and the degradation of whole sectors of the economy are gradually turning from an economic problem into a socio-political issue.

Obviously, the current model must be changed. At the same time, this problem resists conventional predominantly market-based methods successfully applied in a different socioeconomic reality. The transition to a new (innovative) development format requires strengthening the creative component and increasing the role of the state.

However, devising an analytical apparatus, which can substantiate the decisions providing successful governmental interventions into economy and which would raise reasonable expectations that those will rectify the situation rather than aggravate it as it had frequently occurred in the past, has not been finalized yet. Thus, the existing models and traditional methods of econometric modeling are aimed at the study of equilibrium processes. They do not quite adequately describe complex economic systems in nonstationary conditions caused by the variability of the external environment and structural adjustments in the absence of unrepresentative data. This is also true of multilevel model constructions represented by optimization and econometric models. We believe that in modern conditions the approaches of the evolutionary theory considering the economy as a dynamic system that grows, develops, and improves, are the most suitable. This theory is based on taking into account all factors and conditions that actually influence or determine the course of economic processes.

In this regard, of interest are the works by M. Allais, R.M. Cyert, H. A Simon, and D.B. Trow [1, 2], which question the hypothesized rationality of the economic behavior of people and organizations. The emergence of new approaches that make it possible to conceptualize a problem situation, analyze

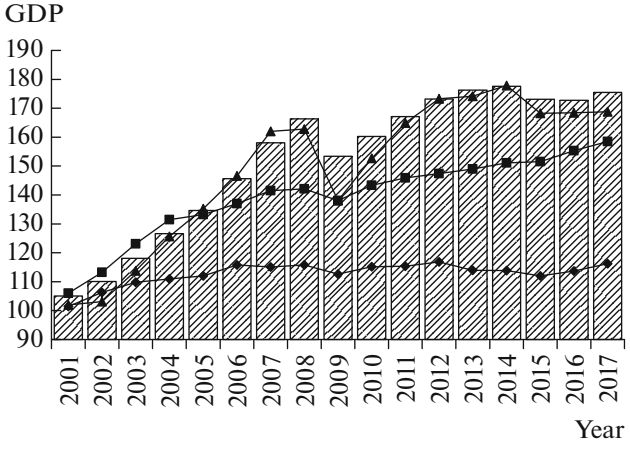

Fig. 1. GDP and production by types of economic activity in the Russian Federation: ▨ GDP; –■– mining; –▲– manufacturing industries; –◆– production and distribution of electricity, gas, and water.

dynamic processes, highlight transitional phenomena, and describe modeled situations in detail using the principles of systemology and synergetics, has become the basis for the development of a new direction in an evolutionary economy – *cognitive economics*. The development of this direction is due to the multidimensional nature of economic processes and their interconnectedness, the impossibility of isolating detailed research of individual phenomena so that everything that happens should be considered together, which in the absence of sufficient quantitative information about the dynamics of processes makes the researcher turn to their qualitative analysis as the only way out.

This work suggests a comprehensive set for the support of strategic decision-making providing a basis for the state economic policy aimed at transforming the existing production system. Thus, the identified target is planned to be reached by devising a cognitive scheme describing relations between macroeconomic indicators of production and agricultural subsystems with institutional, credit, and monetary ones and by constructing a cognitive model, based on which performance indicators of the Russian economy will be determined for the formulated scenarios.

Methods and instruments. ***Cognitive map: factors and relationships.*** The cognitive approach we employed made it possible to introduce into the scientific use some fundamentally new elements of decision support. The developed cognitive map of the Russian economy can help improve the quality of governance in creating an innovative economy in the Russian Federation.

The proposed toolkit makes it possible to identify the main factors, the impact on which sets the system of primary impulses, which determines the development of the entire economy. Special attention was paid to the controversial nature of the impact made by the world oil and gas prices on the character of technological development in the Russian Federation [3]. Figure 2 shows the cognitive scheme of the relationship between the main macroindicators of the economy and natural resource subsystems (products of the agro-industrial complex and extractive industries).

The formulated concepts of the model allow us to proceed to the second stage of creating a cognitive scheme, identifying relations between them. At this stage, quantitative estimates of the mutual influence of factors used in the model are determined. The interconnection of factors, formalized and expressed by the corresponding mathematical relations, allows us to proceed to the construction of a cognitive mathematical model.

In some cases, impact of factors can be assessed based on the experts' opinions and can be expressed quantitatively using the scale [–1, 1] or linguistic variables, i.e., "strongly," "weakly," and "moderately." In this case, it is advisable to use the methods of modeling fuzzy cognitive maps specially developed for this situation [5–8].

Thus, the relationship between the factors presented in the cognitive scheme can be assessed based on exact methods, fuzzy logic, and expert estimates as well as their combination. Completion of the second stage of creating a cognitive scheme allows one to proceed to the direct construction of a cognitive model.

Representation of the cognitive map by directed (weighted directed) graph: forecasting changes in the evolutionary system of interrelated indicators. As indicated in [3], the structure of a complex socio-economic system represented in the form of a cognitive scheme (map), can be displayed as a directed graph (digraph). The vertices of such a graph correspond to the factors describing the system and the arcs (edges) connecting them stand for the causal relationships between the factors. The use of cognitive models in the form of signed digraphs was proposed by R. Axelrod [9]. The main properties of signed graphs are described by F.S. Roberts [10]. A signed graph is a graph in which each edge has a direction and weight +1 or –1 abbreviated as "+" and "–". The "+" sign denotes a positive relationship, the sign "–" a negative one. The feedbacks in the system are represented by loops. There can be two types of loops, i.e., positive (positive feedback) and negative (negative feedback). When there are many positive loops this implies instability: small values of input pulses grow with time and "shake" the system, which can lead to its destruction. Negative loops have a stabilizing effect, they seem to "quench" the deviations and maintain the stability of the system.

It is easy to see (Fig. 2), due to the presence of structural elements and the relationships between them, there are two distinct feedback loops.

A positive feedback loop is created due to the positive development of such system components as institutions, infrastructure, quality of human capital, industrial policy, and the increasing growth in value-added in sectors of the economy. The latter, in turn, leads to an increase in GDP and the emergence of new ways for improving these components owing to growing budget opportunities. However, the observed negative feedback loop determined by monetary regulation associated with the impact of the exchange rate and oil prices, suppresses the continuous growth of the GDP. Thus, the interaction of qualitatively different processes contributes to the stabilization of the economic system.

A signed digraph can be interpreted as a structural model of the process. A more accurate parametric model can be constructed by assigning various numerical values (weights) to the arcs of the digraph, which results in a *weighted digraph*. Such a weight is inter-

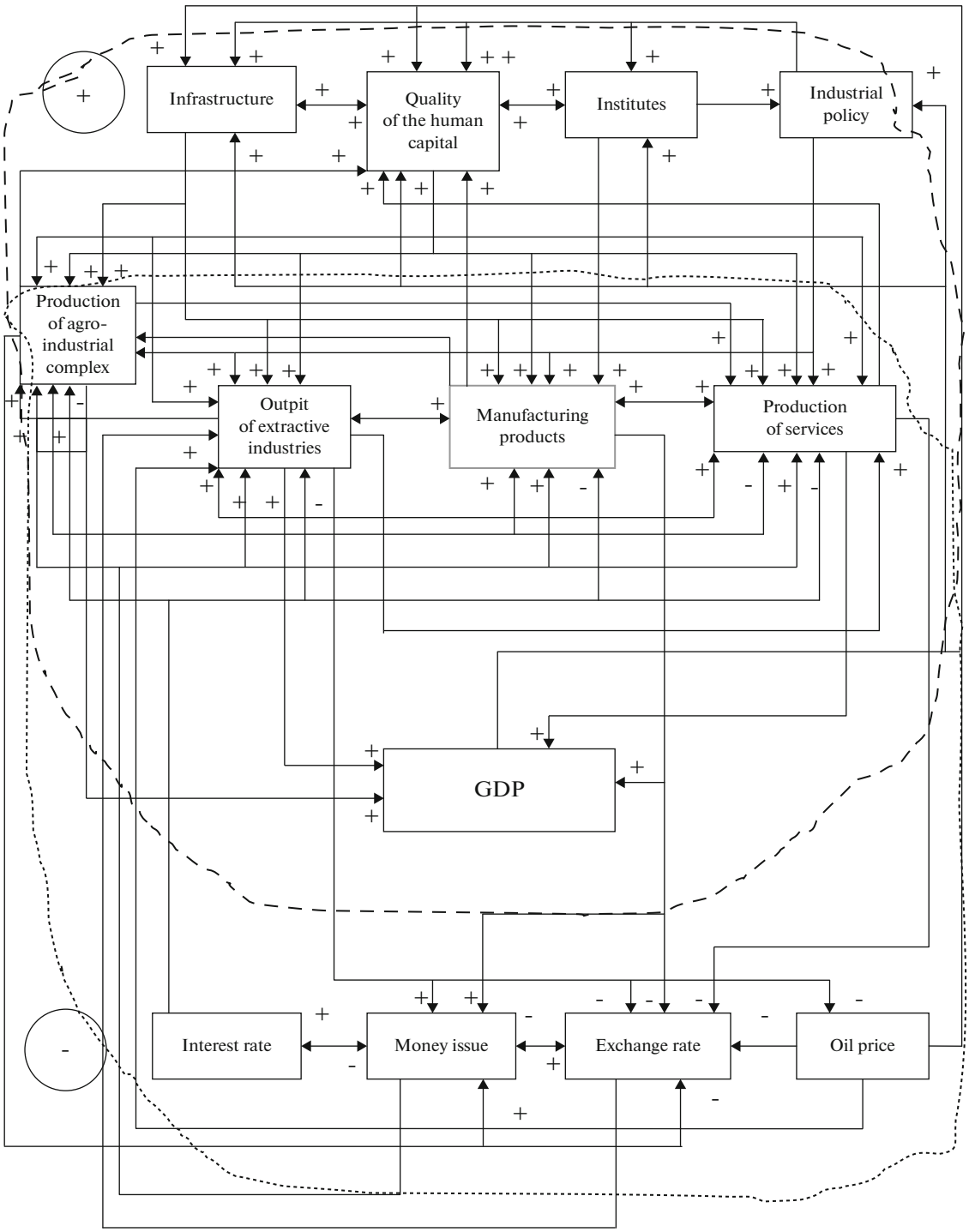

Fig. 2. Cognitive scheme of interrelations between macroeconomic indicators in the Russian Federation.

preted as a relative impact force and may be positive (reinforcing effects) or negative (weakening effects).

By setting the values at any vertex of the graph, we can determine the changes in its other vertices. This problem, unlike the analysis problem, is a forecast one. This dynamic problem is solved using the pulse process [10].

The considered methodological approach enables taking into account a large amount of different-quality data; operating (in order to measure constraint force) indicators other than the correlation coefficients (in case of high uncertainty regarding the constraint force, +1, i.e., the connection is positive, –1, i.e., the connection is negative, and 0, there is no connection);

Table 1. Matrix of socio-economic system development scenarios, % change

Scenario	Oil price	Exchange rate	Money issue	Interest rate	Infrastructure	Human capital quality	Institutes	Industrial policy	Extractive industry output	Manufacturin output	Production of services	Agricultural output
The current trend of economic development	0	0	0	0	0	0	0	0	1.5	0.3	0.7	2.5
Priority development of the primary sector of the economy	10	0	0	0	0	0	0	0	3.0	0	0	0
Unfavorable conditions for the primary sector of the economy	−10	0	0	0	0	0	0	0	1.5	0	0	0
Optimistic non-primary scenario	−10	0	0.5	−0.5	1	2	1	2	1.5	2.0	2.0	2.5
Optimistic scenario for all sectors of the economy	10	0	0	−0.5	1	I	1	2	1.5	2.0	1.0	2.5

Table 2. GDP dynamics in various scenarios, percentage of the growth

Scenario	Step of the process										
	0	1	2	3	4	5	6	7	8	9	10
The current trend of economic development	0	0.85	1.07	1.25	1.36	1.43	1.47	1.50	1.51	1.52	1.53
Priority development of the primary sector of the economy	0	0.48	1.30	1.53	1.74	1.86	1.92	1.96	1.99	2.01	2.02
Unfavorable scenario for the development of the primary sector of the economy	0	0.24	−0.31	−0.40	−0.51	−0.57	−0.60	−0.62	−0.63	−0.64	−0.65
Optimistic non-primary scenario	0	1.50	2.16	2.73	3.04	3.23	3.36	3.44	3.49	3.52	3.54
Optimistic scenario for all sectors of the economy	0	1.29	2.94	3.68	4.19	4.50	4.67	4.79	4.86	4.90	4.93

measuring the stability of the cognitive model represented by the digraph.

The limitations of this approach (as, incidentally, any other, operating with a large number of fairly uncertain data) is due to the probability of obtaining unstable solutions caused by the presence of positive and negative feedback connections in the system. However, this disadvantage is compensated by the large research potential, simulation capabilities of the model, which make it possible to put forward and test certain hypotheses about the nature and strength of the connection of individual factors.

Modeling results. We consider the results of simulation modeling for various scenarios of economic development (Tables 1 and 2).

Scenario 1. Current trends of economic development. *Relatively steady growth is retained in the primary (raw materials) sector of the economy (by about 1.5% on a year-on-year basis). The exchange rate is stable. There is no targeted stimulation of innovative growth or activation of industrial policy by measures of monetary policy. The main objective of monetary policy is to contain inflation. The agricultural sector is actively developing showing production growth up to 2.5%. Growth rates in the manufacturing and service sectors do not exceed 1% (0.3% and 0.7%, respectively). According to this scenario, the average annual growth rate of the economy tends to 1.5%.*

This scenario, according to Churchill's apt expression, is based on the principle "Generals always prepare for the last war". The scenario assumes a policy of Russia's integration into the global economy based primarily on market forces. For the last decade, this strat-

egy has integrated the Russian economy into the world market only by aggravating its dependence on the rest of the world instead of promoting the priority development of industries of national specialization [11]. The only exception is the agricultural sector. However, its relatively high growth rates are due to a greater extent to the external influence on the Russian economy than to the effective state regulation of the agricultural sector. In the face of tougher sanctions aimed at limiting the ties of the Russian economy with the world economy, this path becomes a wild-goose chase.

On the whole, the considered scenario adopts the stagnating functioning of the national economy, which, in the context of the continuing growth in the world economy, predetermines the further backlog of Russia with the threat of its being "ousted" into the marginal zone of the modern world.

Scenario 2. Priority development of the primary sector of the economy. *Favorable conditions are retained in the market for oil and gas products (oil prices rise by 10%). The revenues of the oil and gas sector double as compared to scenario 1. Against the background of a growing primary sector, support for other sectors of the economy is weakening. As a result, the economy is growing at a steady but insignificant rate (within 2%).*

This scenario can be considered as one of the most dangerous formats for the development of the Russian economy. Calculations show that the objective benefit for Russia—the global situation of high prices for oil and gas resources—without purposeful efforts to formulate an industrial policy and a monetary policy adapted to the given conditions, turns into "evil". Indeed, strengthening the national currency does not hinder the advanced development of the extractive industries and nontradable services but *effectively* suppresses the development of the manufacturing industries, "mummifies" the Russian institutional system, which is far from ideal, and but weakly promotes the qualitative improvement in human capital.

Scenario 3. Unfavorable scenario for the development of the primary (raw materials) sector of the economy. *Calculations based on this scenario clearly demonstrate the limitations of the current Russian economic policy. On the assumption that oil prices are reduced by 10%, the growth rate of the economy drops by about 1/3.*

The Russian economy is simply unable to resist the unfavorable external oil and gas situation. The economy is surely entering a recession, since there are no pronounced internal growth drivers in the framework of the current economic policy.

Scenario 4. Optimistic scenario for non-primary (non-raw materials) sector. *Oil quotes are declining; the current trends in the development of the natural resources sector remain the same. A priority growth of innovative manufacturing industries and the agricultural sector is observed as well as increasing demand in the service sector. With this scenario, annual economic growth exceeds 3.5%.*

The fundamental difference between scenario 4 and scenario 3 is that the driver of economic development in this case is not market forces, which in theory (but not in Russian practice!) "put everything in its place themselves," but the activation of industrial policy. In the model, the activation of industrial policy is primarily understood as a sharp increase in funding for existing state programs, especially in the block "innovative development and modernization of the economy" [12]. The increase in funding enables faster achievement of the goals set in the programs, gives a powerful impetus to the development of manufacturing and mining industries, to enhancing the quality of human capital, production and social infrastructure, forms the basis for setting even more ambitious national development goals, and contributes to the country's economy overcoming the long-term stagnation. In fact, this is about strengthening the planned aspect in the economy, but on a market rather than on an administrative basis. While in the planned economy of the Soviet Union, the achievement of the set goals was determined by the distribution of material resources in accordance with administrative decisions, in modern conditions the development tasks are supposed to be accomplished by mobilizing financial resources. This scenario suggests stimulating monetary policy (the key interest rate is reduced by 0.5% and the growth in the issued money supply is increased by 0.5%).

Securing new qualitative change of the industrial policy is impossible without improving the existing institutional system. The issue of institutional development should be considered in a separate study. Thus, in the Global Competitiveness Report, progress/regress of the national institutional system is evaluated based on the 21st indicator [13]. The calculations performed on determining the numerical parameters that affect the change in the quality of institutions and GDP growth primarily allow for such factors as the effectiveness of budget expenditures, barriers to setting up and running a business, and administrative pressure on business.

Scenario 5. Optimistic scenario for all sectors of the economy. *The scenario involves a combination of the forecast conditions of scenario 2 (growth in demand and increase in oil prices by 10%) and scenario 4 in part by activating industrial policy and strengthening the stimulating role of monetary policy (the key interest rate decreases by 0.5%, the money supply is increased by 0.5%). The implementation of this scenario results in attaining the maximum (5%) GDP growth rates.*

The advantage of this scenario is that it makes it possible to avoid the negative effect produced by the strengthening of the national currency (associated with growing rental income from the sale of oil and gas resources in the world market) due to active industrial and monetary polices that allow one to direct foreign currency resources to development rather than to use

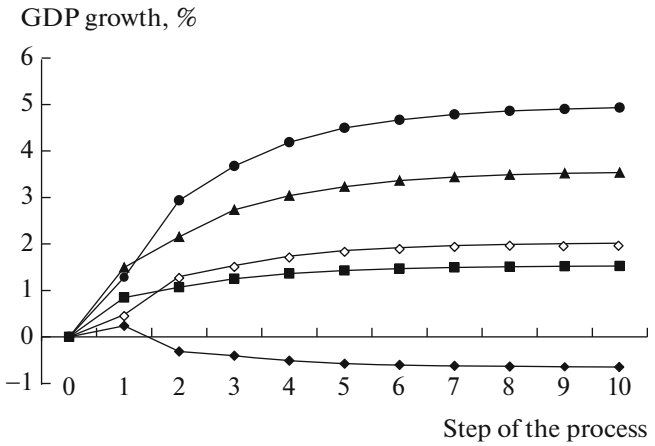

Fig. 3. GDP growth rates in various scenarios of economic development by the steps of the simulation process: —▲— optimistic scenario of nonprimary; —■— current trends of economic development; —◇— priority development of the primary sector; —◆— unfavorable scenario for the primary sector; —●— optimistic scenario for all sectors of the economy.

them for the suppression of manufacturing industries and the service sector.

The GDP growth rates for the considered scenarios are shown in Fig. 3.

Conclusions. The conducted studies suggest that methods of cognitive modeling open up new opportunities for conceptualizing the problem situation, meaningful analysis of dynamic processes, identifying, (and managing) transition states as well as qualitative and quantitative description of simulated situations based on the principles of systemology and synergetics. The employed apparatus made it possible to create a cognitive map and, on its basis, a cognitive model of the Russian economy identifying the most important resource blocks (the mining industry and agriculture).

The analysis shows that the most productive factor in terms of increasing GDP growth rates is improving the quality of the industrial policy pursued. The second most influential factor in the development of the national economy is monetary policy. Shifting the main emphasis from anti-inflationary guidelines to creating conditions for economic growth would make it possible not only to ensure the progressive development of the economy but also to reduce inflation. A significant impact on economic growth is also made by the improved quality of institutions. The calculations show that the intensification of industrial and monetary policies as well as progress in improving the quality of the institutional system create a synergistic effect markedly promoting the investment processes in the economy.

The impact of oil prices, a factor external to the Russian economy, is contradictory. A price increase gives a short-term positive effect i.e., GDP growth due to the development of extractive industries and services against the background of degrading manufacturing industries. A decrease in oil prices, on the contrary, in the short term leads to some decrease in GDP due to stagnation in the extractive industries and reduction in services, but at the same time "triggers" the development of the manufacturing industry and of the agricultural sector. Simulation modeling based on the cognitive model reveals that priority development of the mineral resources sector (extractive industries) even in conditions of a favorable external environment is not able to ensure sufficient economic growth and sustainable socio-economic development.

We believe the most pressing task of the day is to focus on the internal factors of Russian economic growth. In doing so, it is necessary to use the possible improvement in the global oil and gas situation as a resource for the development of domestic infrastructure and those areas of industrial, agricultural, and institutional policies that, without provoking a Dutch disease, would create the basis for generating investment. The successful implementation of investment programs will almost inevitably lead to the creation of a modern innovation economy in the Russian Federation.

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