

ANALYSIS OF THE STATE OF THE NATIONAL ECONOMIC SYSTEM: PROBLEMS AND THEIR SOLUTIONS**Verigo A.**

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Abstract

This article examines the nature of the problem related to analysing the state of the national economic system. An approach to solving this problem is proposed. The problem has been broken down into its constituent structural elements, which enabled the development of an algorithm to address it. The developed algorithm takes into account the main methodological aspects of analysing multi-connected, multi-parameter, dynamic systems, which may include linear, linearised and non-linear subsystems. The algorithm serves as a basis for the justification and development of econometric models for the management of macroeconomic processes, as well as for the implementation of adaptive control of the national economic system. The proposed algorithm comprises three analysis loops: the main analysis loop, the analysis loop for types of influences on the system, and the analysis loop for the system's self-tuning capability.

Keywords: systems research; systems theory; adaptive control theory; national economic system; management of the national economy.

Introduction

The foundation of the effective national economic system's management lies in the realisation of all management functions, including the analysis function. Issues relating to the analysis, structure and management of the national economy have been extensively studied in the economic literature. Such famous scientists as V. N. Shimov, A. I. Korotkevich, I. V. Novikova, Yu. M. Yasinsky, I. V. Blauberg, E. G. Yudin, A. Schueller, H. G. Krusselberg and others have significantly contributed to the study of the analysis and structure of the national economy (for more information, see the publication [1]). The research is based on contemporary achievements in management theory, systems analysis and the theory of adaptive systems control, as presented in the scientific works of A. G. Aleksandrov [2], V. N. Afanasyev [3], E. M. Borodina, K. N. Borodina [4], V. A. Borodenko [5], V. A. Besekersky, E. P. Popov [6], A. P. Vlasov [7], B. S. Dobronets, O. A. Popova [8], V. N. Kalinin [9], D. A. Novikova [10], O. V. Folka, I. F. Ivashkina [11], I. Yu. Tyukina, V. A. Terekhova [12] and others, as well as a comprehensive study of the substantive characteristics of the 'national economic system's' concept (for more information, see the publication [13]).

However, there remains insufficient research into the analysis of the state of the national economic system in terms of its dynamics (development, evolution, transformation), the nonlinearity of its components, and the diversity of interrelationships between its structural elements and the parametric indicators that characterise them. Solving this problem will contribute to the justification and development of econometric models for managing the national economic system, as well as to the implementation of an adaptive control system. The adaptive control system for the national economic system comprises three control loops (the main loop, the disturbance control loop, and the self-tuning loop). This approach to adaptive control will ensure the speed, accuracy, and stability (stability, reliability) of the param-

eters (characteristics, properties) of the national economic system. Taking into account the control loops described above, corresponding loops for analysing the state of the national economic system have been identified.

Results and Discussion

The national economic system comprises numerous subsystems. These subsystems are in the state of constant development, driven in part by the influence of various external and internal factors. The problem of analysing the state of the economic system 'is linked to assessing the state of a dynamic system ... at a given point in time ... and studying the system's response' [9, p. 36]. The analysis is based on observing and recording various parameters that reflect the functioning of the economic system.

The key to solving the problem lies in identifying an algorithm for analysing the system. The complexity of analysing the state of the national economic system stems from the presence of non-linear subsystems (elements) and, consequently, the need to transform them into linear systems. This is required in order to describe the mechanism of its functioning using a linearised mathematical loop. At the same time, the national economic system, when viewed in terms of its subsystems, may include both non-linear and linear elements. In this regard, to address the aforementioned problem, we propose considering three areas of analysis, which include the mathematical description and interpretation of the characteristics of the functioning of the national economic system's linear, linearised and non-linear structural elements [14]: 1) the analysis of the economic system's linear elements (subsystems) influence on its behaviour; 2) the analysis of the economic system's non-linear elements' (subsystems') influence on its behaviour, which can be studied as linear; 3) the analysis of the influence on the behaviour of the economic system of its fundamental non-linearities, i.e. those subsystems that cannot be approximated by linear relationships. These areas of the analysis are integrated into each of

the three loops for analysing the state of the national economic system.

The first analytical loop – the main loop – involves an analysis of the system's initial state. An important element of this loop is the identification of observable and unobservable parameters (indicators, trends, interrelationships, etc.) that reflect the stable characteristics of the national economic system's state. The main observable parameters include macroeconomic indicators presented in the system of national accounts, as well as their growth rates. The analysis is based on identifying the state of the system through its explicit and implicit reactions to various types of influences. Equally important for analysing the state of the system is identifying the interrelationships between changes in the system's parameters (qualitative and quantitative characteristics) and changes in the corresponding system reactions. Reactions may include [14]: changes in economic proportions; various economic and social consequences; changes in the indicators characterising the efficiency and sustainability of the economy's functioning; an increase in consumer demand; an increase in the volume of domestic and foreign investment; changes in social indicators (increase in the birth rate, decrease in the mortality rate, etc.). Both explicit and implicit (weak) reactions of the national economic system to a particular type of impact are taken into account. Qualitative identification of these interrelationships enables the analysis and assessment of unobservable economic parameters.

A key area of the analysis involves the study of almost-free movements and system responses, the examination of different types of environments, and their classification (deterministic, stochastic, target, unknown [9, p. 32]). The results obtained will form the basis for: identifying the system's responses to various types of influences; identifying the types of relationships between system-defining parameters; assessing the impact of different types of influences on the system. A comprehensive understanding of the economic significance of the qualitative and quantitative characteristics of the system's almost-free motions and responses, as well as their description using appropriate mathematical tools, will enable the transition to the analysis of the second loop.

The main methodological challenges in analysing the state of the national economic system are [14]: a) determining the point in time (or time interval) of the system's initial state; b) determining the parameters for

analysing the system's initial state; d) identifying the cause-and-effect relationships underlying changes in the system's state, its parameters and properties, which includes: 1) identifying and investigating the types of cause-and-effect relationships that contributed to the formation of the economic system's state at the time under study; 2) identifying cause-and-effect relationships that have lost their relevance; 3) identifying new (directions of transformation of 'the old') cause-and-effect relationships.

Determining the point in time (or time interval) of the system's initial state. This may be any point in time (or time interval) that most fully reflects (characterises) the negative or desired (target) characteristics of the national economic system.

Determining the parameters for analysing the initial state of the system.

The first step in analysing the initial state of the system is to analyse the observable parameters of the national economic system. In accordance with the system of national accounts of the Republic of Belarus, the main macroeconomic indicators used to describe and analyse macroeconomic processes are: gross domestic product, gross national income, gross value added, gross profit, gross savings, output, the volume of exports and imports of goods and services, intermediate consumption, taxes paid, compensation of employees, gross profit and gross mixed income, property income, final consumption expenditure, social security contributions, social benefits, capital transactions, etc. [15]. However, as scholars note, GDP does not take into account: 1) the quality of life indicators (level of education, life expectancy, environmental conditions, life satisfaction, etc.); 2) potential future risks; 3) parameters of the unobserved economy; 4) the purchasing power of currencies and other factors. It should be noted that some of the methodologies used to calculate macroeconomic indicators are disputable. These aspects must be taken into account when interpreting the results of the analysis.

Let us examine the trends in selected macroeconomic indicators (Table 1). As can be seen from Table 1, there is a positive trend across all the indicators presented. In general, in terms of their economic content, the indicators of gross value added, gross domestic product, gross national income and gross savings reflect the processes of formation, distribution, redistribution and utilisation of resources at the level of the economy as a whole.

Table 1

Trends in selected macroeconomic indicators

Indicator	Period			Growth rate, %	
	2021	2022	2023	2022 / 2021	2023 / 2022
Output of goods and/or services at current prices, million roubles	337989	371180	413385	109,82	111,37
Labour productivity: manufacturing sector (at constant prices, as a percentage of the previous year)	102,8	97,2	108,1	-	-
Labour productivity: services sector (at constant prices, as a percentage of the previous year)	103,5	96,4	103,2	-	-
Gross value added at current prices, million roubles	154853	172959	191266	111,69	110,58
Gross savings at current prices, million roubles	52465	51034	57908	97,27	113,47
Gross domestic product at current prices, million roubles	176879	193741	217969	109,53	112,51
Gross national income at current prices, million roubles	170386	185608	210906	108,93	113,63

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

Gross domestic product is a key indicator in the system of national accounts. It can be calculated using three methods: the income approach, the expenditure approach, and the production approach. Analysing the composition and structure of gross domestic product using these methods is crucial for assessing the performance of the economy. Table 2 shows the trend in gross

domestic product calculated by source of income. As can be seen from Table 2, in 2023, compared with 2022, there was positive growth across all indicators. The highest growth was observed in the indicator of net taxes on production and imports, with an increase of over 29.6%.

Table 2

Trends in gross domestic product by source of income

Indicator	Period			Growth rate, %	
	2021	2022	2023	2022 / 2021	2023 / 2022
	Amount, millions of roubles	Amount, millions of roubles	Amount, millions of roubles		
Compensation of employees at current prices	82377,3	92336,3	106657	112,1	115,5
Net taxes on production and imports at current prices	22918	21825,8	28280,7	95,2	129,6
Gross profit and gross mixed income at current prices	71583,7	79578,9	83031,4	111,2	104,3

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

Table 3 below shows the structure of gross domestic product by source of income. There is no single optimal structure for the composition of gross domestic product by source of income. One positive aspect worth noting is that the growth rates of gross profit and gross

mixed income exceeded the growth rates of workers' wages. As can be seen from Table 3, no significant changes in the structure of gross domestic product were observed during the period under review.

Table 3

Structure of gross domestic product by source of income

Indicator	Period			Percentage-point change, p.p.	
	2021	2022	2023		
	Share of GDP, %	Share of GDP, %	Share of GDP, %	2022 / 2021	2023 / 2022
Compensation of employees at current prices	46,57	47,66	48,93	1,09	1,27
Net taxes on production and imports at current prices	12,96	11,27	12,97	-1,69	1,7
Gross profit and gross mixed income at current prices	40,47	41,07	38,09	0,6	-2,98

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

Table 4 shows the trend in GDP calculated using the income approach. All components of 'final consumption expenditure' show a positive trend, with growth rates exceeding 10%. In 2023, a positive trend can also be observed in 'gross capital formation'.

Table 4

GDP growth calculated using the income approach

Indicator	Period			Growth rate, %	
	2021	2022	2023		
	Amount, millions of roubles	Amount, millions of roubles	Amount, millions of roubles	2022 / 2021	2023 / 2022
Final consumption expenditure	119725	136897	156468	114,34	114,3
of which:					
households	88838,7	102227	116057	115,07	113,53
public organisations	29744,1	33379,4	38911,6	112,22	116,57
non-profit institutions serving households	1142,1	1290,2	1499,4	112,97	116,21
Gross capital formation	43124,4	41844	53863,8	97,03	128,73
of which:					
gross fixed capital formation	39923,6	37678,2	49163,7	94,38	130,48
changes in inventories of consumables	3200,8	4165,8	4700,1	130,15	112,83
Net exports	9992,5	11775,9	1021,8	117,85	8,68

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

Table 5 presents the structure of GDP calculated using the income approach. As in the previous case, there is no universally accepted optimal ratio between the structural components. Based on this structure, the qualitative characteristics of the resulting indicator can

be discussed. The structure of income use should contribute to sustainable economic growth, raise the standard of living of the population, ensure the necessary investment in fixed capital and a positive net export.

Table 5

Structure of GDP calculated using the income approach

Indicator	Period			Percentage-point change, p.p.	
	2021	2022	2023	2022 / 2021	2023 / 2022 .
	Share of GDP / within the group, %	Share of GDP / within the group, %	Share of GDP / within the group, %		
Final consumption expenditure	67,69	70,66	71,78	2,97	1,12
of which:					
households	74,2	74,67	74,17	0,47	-0,5
public organisations	24,84	24,38	24,87	-0,46	0,49
non-profit institutions serving households	0,95	0,94	0,96	-0,01	0,02
Gross capital formation	24,38	21,6	24,71	-2,78	3,11
of which:					
gross fixed capital formation	92,58	90,04	91,27	-2,54	1,23
changes in inventories of consumables	7,42	9,96	8,73	2,54	-1,23
Net exports	5,65	6,08	0,47	0,43	-5,61

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

GDP calculated using the production method comprises the sum of gross value added by economic activity and net taxes on products [15]. The optimal structure depends, first and foremost, on the country's economic development model and priority economic activities. The optimal structure of GDP calculated using the production method is characterized by a predominance of sectors (economic activities) with high value added.

The second element of initial system's state analysis of the 'unobservable parameters' of the economy. Within the loop of the proposed algorithm for analysing

the initial state of the national economic system, the unobservable economy is examined on the basis of identified patterns in the functioning of the national economy. The identification of the 'unobservable parameters' of the economy is carried out using weak signals that reflect changes in economic processes and phenomena.

As can be seen from Table 6, the largest share of the unobservable economy falls within the services sector.

Table 6

Share of the unobserved economy (in current prices, as a percentage)

Indicator	Period			Percentage-point change, p.p.	
	2021	2022	2023	2022 / 2021	2023 / 2022
The services sector as a proportion of gross domestic product	8,1	7,4	7,5	-0,7	0,1
The services sector as a proportion of gross value added by economic activity	16,6	15,3	15,4	-1,3	0,1
The manufacturing sector as a proportion of gross domestic product	2,5	3,7	3,2	1,2	-0,5
The manufacturing sector as a proportion of gross value added by economic activity	6,6	9,1	8,1	2,5	-1
Total by economic activity in gross value added	12,1	12,4	12,1	0,3	-0,3
Total by economic activity in gross domestic product	10,6	11,1	10,7	0,5	-0,4

Note: Compiled by the author based on data from the National Statistical Committee of the Republic of Belarus [15].

For effective management of the national economic system, it is important to increase the accuracy of estimating the volume of the unobserved economy. To address this issue, we shall adopt a descriptive definition of the unobserved economy – that is, defining the subject of study through its properties and external manifestations. At this stage of the analysis, it is necessary to identify: the economic processes that occur in an unobserved economy; non-systemic (chaotic) manifestations in the economy. The basis for analysing the

unobserved economy is the identification of cause-and-effect relationships.

Identification of cause-and-effect relationships.

To identify causal relationships, various parameters (indicators) are examined. These parameters may include: 'key macroeconomic indicators ... , indicators characterising the causes and factors of growth, the degree of economic balance, the type of reproduction, ... the extent of a country's integration into the global economy' [16, p. 54]; parameters of macroeconomic

regulation [17, p. 5] and others; parameters characterising the social outcomes of the economy's functioning [16, p. 54] and others. The main indicators (parameters) for analysing the state of the national economic system may vary depending on the priority areas and objectives of the national economy's development. Such objectives may include: economic growth, full employment, price stability, economic efficiency, and maintaining a balance of trade [18, pp. 20–21].

The results of the analysis of the system's initial state, as well as the identified patterns and interrelationships between the elements of the national economic system, form the basis of the second stage of the analysis.

The second analytical loop concerns the analysis of the types of impact on the national economic system. This loop involves the identification, analysis and assessment of the system's voluntary and involuntary movements and reactions. The main methodological tasks are (for further details, see publication [19]): 1) recording and evaluating the movement (change in state) of the economic system [9, pp. 31–35]; 2) calculating the time lag of the system's response to random (chaotic) and targeted (control) influences; 3) assessment of the oscillatory nature (volatility) of the economic system, its susceptibility to external influences and the presence of undamped oscillations; 4) assessment of the system's inertia; 5) calculation of the 'time constant' of the control input; 5) quantitative assessment of the non-linear elements of the economic system.

The assessment of nonlinear elements of the economic system involves: 1) replacing them with their average characteristics; 2) selecting approximation functions; 3) identifying input signals (impacts) in terms of their small and large variations; 4) constructing a corresponding system of equations that reflects changes in the system's integrative properties.

A key aspect of implementing the proposed algorithm is the analysis of: the distinctive features of the system; the core economic activities; the stable links between the system's elements; the types of direct and indirect external influences that affect changes in the parameters and properties of the national economic system; and the system's known responses to specific types of influences. When conducting the analysis, it is necessary to take into account that the system's motion may be free in some directions and constrained in others. The importance of this stage is determined by the following: an accurate mathematical description of known input influences, combined with a comprehensive description of the system's stable characteristics (a mathematical description of the system's state, including its almost-free movements and reactions), is 'sufficient for the unambiguous determination of the future output situation' [9, p. 28].

Once we have thoroughly identified the system's free-running movements and responses, we can proceed to analyse the system's responses to various types of control inputs. An economic system is always subject to control inputs. Control inputs may differ in terms of: direction (vector), magnitude, type and frequency.

An analysis of the national economic system within the loop of a study of the system's forced movements and reactions involves addressing two main tasks: 1) examining the types and forms of regulatory intervention in accordance with the state policy being implemented; 2) examining the types and forms of external targeted and non-targeted influences (disturbing influences). This analysis is based on a constructive description of the structure of the economic system, which must answer the question of how to form the system. From a constructive perspective, any system, including an economic system, can be represented as: a unity of inputs (targeted and non-targeted influences); models of the economic system; and outputs (system reactions). In the applied aspect, for the purposes of a constructive description of the structure of the national economic system, the types and forms of controlling influence that have occurred in the past, and which are available for use in the current and/or forecast periods, are substantiated and described by mathematical equations. The result of this analysis is a classification of cause-and-effect relationships according to their interconnection with types of influence (controlling, perturbing) on the national economic system. The outcome is a mathematical description of management methods and tools.

Particular attention is paid to the evaluation of the increment of the argument, which yields the increment of the function. This allows us to assess the change in the state of the economic system at a given point in time (t_n). An important outcome of the analysis of the system's free and forced movements and reactions is: a) their integral evaluation; b) an assessment of the national economic system's resilience to targeted and non-targeted influences. The comprehensive assessment of the system's free and forced movements and reactions is one of the most complex aspects, as even the slightest error in the mathematical representation (formulaic description) of the process under consideration can lead to significant negative consequences.

An important stage of the second loop of analysis involves analysing the parameters of the national economic system following the application of control measures. Based on the results of this analysis, conclusions are drawn regarding the controllability, stability and operational efficiency of the national economic system, as well as the effectiveness of the control system. Based on these results, the optimal control law (a mathematical description of the control function) is selected. Based on the results of the analysis, adjustments may be made to the controlled object (the parameters and properties of the national economic system). The basis for such a management decision is an analysis of the system's transient characteristics upon reaching its target (forecast) state.

The final stage of the second loop of analysis involves the development of a methodological toolkit for assessing synergistic effects. The basis of this methodological toolkit lies in identifying vertical and horizontal links between elements of the national economic system; these links form the vertices of graphs, reflect the stable nature of the interrelationships, and ensure the development (evolution, transformation) of the economy. These elements may include [14]: 1) sectors

of the economy and their corresponding institutional units; 2) spheres of the economy; 3) aggregates of natural and material resources; 4) various levels of interaction between economic actors [1]; 5) groups of 'economic actors ensuring the circulation of goods and income' [1]; 6) various proportions between the system elements described above; 7) economic operating conditions (provisions of national and international law). The identified relationships are classified and described using corresponding integrated indicators. The resulting integrated indicators form the basis for assessing the synergistic effect of the management decisions taken.

The third analytical loop concerns the analysis of the national economic system's capacity for self-adjustment. The theoretical basis comprises the fundamental laws of economic theory and the laws governing the development of economic systems. The methodological objectives of this section are: to assess the permissible level (values, parameters) of the system's transient characteristics; and to initiate the system's self-adjustment mechanism. The main categories of this line of analysis [20]: 'transient characteristic of the system'; 'corrective mechanism' (corrective method, tool), which is based on the analysis of function extrema and bifurcation points; 'overshoot', which depends on the magnitude of the first disturbance (the magnitude of the deviation between transient and target parameters); volatility of system indicators; 'delay time' of the system's response to the corresponding control action.

Conclusion

This article presents, for consideration, an algorithm developed by the author for analysing the state of the national economic system, which is a complex, open, dynamic, highly interconnected, and multi-parameter system. The algorithm comprises three analysis loops: the main loop (identification and analysis of observed and unobserved parameters of the national economic system, description of its initial and target states); a loop for analysing types of impact on the national economic system (analysis of intended and unintended impacts, which includes analysis of free and forced movements and reactions of the system); a loop for analysing the national economic system's capacity for self-adjustment, which enhances its adaptability to various types of impact. The developed algorithm for analysing the state of the national economic system is designed to reflect objective processes in the economy and will enable the acquisition of comprehensive, multi-level, quantitative and qualitative information regarding its characteristics, properties, parameters and reactions to various types of impacts. The application of the algorithm will enable the formation of an adaptive management system for the national economic system, which will ensure the speed, accuracy and stability (reliability) of the system's parameters (characteristics and properties).

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