

THE MANAGEMENT OF REGIONAL INFORMATION SPACE IN CONDITIONS OF THE DIGITAL ECONOMY

The article suggests an original uniquely designed model based on the entropic approach and the method determining the synergizing effect from the convergence of information spaces in the context of the digital economy. The model includes a 3D-modeling-built surface characterizing the reduction of the entropy of information systems clusters in the regional information space, which occurs in the process of network convergence. This model defines the entropy changes for the information systems clusters with the most typical parameters based on “The State Information System Registry of St. Petersburg” in terms of the number of modules, general typology, and functional purpose. Moreover, the model considers ranges of specific indicators characterizing the real regional information systems of St. Petersburg. We have concluded that the synergetic effects of convergence in the context of the digital economy lead to a reduction in the regional information space entropy. We have discovered that the increasing number of the converged clusters of information spaces leads to a stable entropy decrease in them. These features allow numerically describing the discovered convergence effects and estimating the effect of digital structural transformations of the economic system on the information space of a region in terms of its management efficiency. We have concluded that increasing the number of information systems involved in the digital convergence processes causes a more considerable entropy reduction and, consequently, a more significant increase in the effectiveness of regional system management. The research has revealed a relevant area of cross-disciplinary research, which consists in the emergence of a whole class of new neural network in the modern digital neural network economy. This research is of practical significance in developing new management algorithms and making effective managerial decisions in the conditions of large-scale digitalization and networking of regional and national management.

Keywords: digital economy, technological revolution, neural network, management, entropy approach, regional information spaces, network convergence, neural network effects, infrastructure, informatization

Neural network

The current digital technologies are considered as the main means for increasing competitiveness, productivity and profitability, and a primal accelerator of innovation-driven economic growth. In July 2017, Federal program “Digital Economics of the Russian Federation” developed by the government of the Russian Federation (Ministry of Communications and Mass Media of the Russian Federation) has been adopted, for a term of up to 2025. For successful implementation of this program, traditional management institutions are transformed, and new management institutions are created on federal and regional-industry levels. Under the influence of currently unrolling neural networkneural network technological revolution, transformational processes take place in all spheres of socioeconomic life, determining quality, type and forms of the implementation for the development of digital stage.

In present-day conditions, a Neural network, integrative-distributed latest generation mega-network is being formed, representing the next-generation Internet operating on the basis of integrative-distributed neural computer networks, socio-neuromorphic interfaces and comprehensive ecosystems of self-learning artificial intelligence. Neural circuits associated with decision-making and social cognition are numerous and frequently activated as a network [1, p. 259–289]. Therefore, the dynamically developing global neural computer network called “Neural network” transforms the nature and form of relations between economic operators and institutions at all levels of socioeconomic life. The implementation of the newest break-through technologies should provide for realization of advantages of leading economies and major companies in the context of increasingly intensive global hypercompetition.

Advanced neural networkneural network technologies transform institutional settings, create principles and algorithms of digital transformations of economic operators’ consciousness, change the definition of objectives, motives and the nature of relations between people in the process of network

interaction, which in its turn results in a change of models of their economic behavior and management decisions being made.

Based on the results available within the framework of this study, the main focus will be on the methodology and experimental investigations comparable to other considerations of neural science methods for interdisciplinary applications [2, p. 140–152].

In particular, in the context of fundamentally new economic development drivers, it is necessary to identify its key vectors as well as create new strategies, goals and objectives for economic operators and regulating institutions. It should facilitate the competitive development for enterprises and industry sectors, as well as the optimization of the use of budgetary funds by state bodies at the federal and regional level.

Thus, a new IT neural network neural network revolution has begun, leading to the formation of interactive Neural mega-network, with its technological core consisting of global hybrid network computer-socio-neuromorphic interfaces. In the setting of neural network technologies dynamic development, a new quality of economics emerges, something that might be called a “Digital Neural network Economics”. It gives rise to a variety of new regularities, operational and control mechanisms, and the formation of qualitatively new neural network processes, products, services and effects.

In 2003, a new discipline called “NeuroEconomics” has emerged, developing on the basis of several sciences synthesis: information economics, behavioral economics, cybernetics, psychology, cognitive neurobiology and neurophysiology. The idea of “neuroeconomics” was introduced into wide scientific circulation by Paul W. Glimcher [3, p. 447–452]. In 2005, a community of neuroeconomists — Society for NeuroEconomics¹ — has been founded and has been actively functioning ever since.

Digital economics gives rise to different institutional management network structures, including state authority institutions at global, federal, regional and local levels. The leading position in the structure institutions for management and regulation of globalizing digital economics is occupied by electronic-network management, regulation and monitoring institutions. The most important of them is the electronic government (e-government), which can be considered an institutional and organizational form of exhibiting and realization of a network administrative human capital. The creation of a comprehensive well-distributed system of e-government and rendering digital government services is currently a priority objective for the majority of leading countries all over the world.

Neural network effects need an adequate monetary and non-monetary evaluation and have to be taken into account in the extended structure of gross national (global) product. Thus, the determination of methodological principles and evaluation methods for polyfunctional neural network effects are of utmost importance, as well as their inclusion and accounting in GNP amount.

Network effect can bring integrative (spatially-distributed and delayed in time) added value.

Thereupon, the Center for Strategic Elaborations (CSE) has prepared a report called “State as a Platform. (Cyber)state for Digital Economics”² published in May 2018. This document notes that the deployment of the state as a platform is focused on citizens that will interact with the digital ecosystem and receive digital services from it according to their needs. The document notes the necessity for the implementation of certain measures:

- creation of a single architecture of state digital platform overcoming the fragmentation of departmental systems and based on integrated data array;
- transfer of all state services into electronic form with remote biometrical identification system, transfer of control-supervising and permission activities into digital format.
- creation of “digital twins” of citizens, organizations, facilities and proactive rendering state services based on “digital twin” development;
- creation of Ministry of digital transformation responsible for implementation of aforesaid changes³.

¹ Society for NeuroEconomics. URL: <http://www.neuroeconomics.org> (Date of access: 23.04.2018).

² Gosudarstvo kak platforma. (Kiber)gosudarstvo dlya tsifrovoy ekonomiki. Doklad [State as a Platform (Cyber)state for Digital Economics. Report]. Retrieved from: https://www.csr.ru/wp-content/uploads/2018/05/GOSUDARSTVO-KAK-PLATFORMA_internet.pdf (date of access: 03.06.2018). (In Russ.)

³ Tsifrovaya transformatsiya gosudarstva. Grazhdanin i gosudarstvo v novoy tsifrovoy realnosti [Digital transformation of a state. Citizen and state in new digital reality]. Retrieved from: <https://www.csr.ru/news/tsifrovaya-transformatsiya-gosudarstva-grazhdanin-i-gosudarstvo-v-novoj-tsifrovoy-realnosti/> (date of access: 08.05.2018). (In Russ.)

The various aspects of neuroeconomics have become the subject of scientific research in the studies of a number of Russian scientists: V.A. Klyucharev, A. Shmids, A.N. Shestakova [4, p. 14–35], A.V. Romanovsky, Ya. V. Shokin [5, p. 42–44], A.K. Solodov [6, p. 5] et. al.

Indicated objectives and tasks as a whole create the need to optimize and streamline the administrative impacts to be used by stakeholders in various sectors of national economics. In many cases, these impacts, by virtue of some limitations, do not lead to anticipated results due to a lack of possibility for their prompt and flexible correction under dynamically changing conditions and ever-strengthening innovation-based hypercompetition. During transfer to the hypercompetitive digital economy, there arise the problem of insufficient promptness, flexibility and efficiency of administrative decisions and procedures of government and regional agencies, resulting frequently in a decrease in competitiveness of both separate enterprises and the whole industry sector. There is a problem of scientific nature, which consists in a lack of common methodological approach to the formulation of neural network paradigm and management of national, industry and regional infrastructure under conditions of neural network transformation of the whole world economic system.

In the context of solving these problems with regard to state administration, it is rational to determine regional information space in the digital economics environment as the subject of this study. The subject of this study consists in the processes of structural transformations and network convergence of informatization industry and corresponding regional regulation institutions.

Theory

The “digital economics” term was first introduced in 1995 in the book “The Digital Economy: Promise and Peril in the Age of Networked Intelligence” by Don Tapscott [7, p. 1–37]. “The Digital Economy” was one of the first studies where the question about how the Internet will change the way of business conduct was considered. According to Thomas Mesenbourg’s study conducted in 2001 [8], three main components of “Digital Economics” concept can be specified:

- infrastructure of electronic business (e-business) (hardware, software, telecommunications, networks, human capital, etc.);
- e-business itself (business operations, any process aimed by organization at computer networks);
- electronic commerce (e-commerce) (transfer of goods via Internet).

Bill Imla notes that new applications dissolve the boundaries and add complexity to economic relations⁴. He confirms his argument, among other things, by mentioning social networks and Internet search. In the last decade of the XX century, Nicolas Negroponte used the metaphor of transfer from processing atoms to processing bits: “The problem is simple: when information is objectified in atoms, a need for all kinds of industrial tools and facilities arises, as well as and huge delivery expenditures. But suddenly, when focus shifts to bits there is no more need for traditional large companies anymore. Independent, individual services via Internet begin to gain significance. This is impossible for a hard copy.”

In this new economics, digital networks and communication infrastructures provide a global platform on which individuals and organizations develop their strategies, interact, communicate and search for information. In one of the modern studies, digital economics was defined as a branch of economics studying immaterial goods with zero marginal value, via network [9].

In the process of innovation and information production of goods and services, high fixed expenses and relatively low marginal costs arise. Under conditions of digital economics, any manufacturer strives to produce, render and sale maximum possible volumes of information products (information services) in order to gain higher profit and compensate for high initial expenses connected with the development of original information product. As noted by R. Viber [10, p. 90], in information-network economics as against industrial one, not the law of decreasing marginal yield but direct network effects are dominating, and this is expressed in increasing marginal yield.

In global information economics, various informational-network effects take place. Informational-network effects are the effects resulting from innovations, from networking, from business integration. Inherently, these are synergy-network (integral) effects expressed in various forms. H.R. Varian distinguishes two primary types of network effects: direct network effects and indirect network effects [11, p. 265, 226]. Sebastian Knoll distinguishes the specific type of cross-business synergy — informational

⁴ The Concept of a “Digital Economy”. URL: <http://odec.org.uk/the-concept-of-a-digital-economy> (Date of access: 17.04.2018).

Growth of number of scientific publications related to digital economics problems in the leading scientific metric databases

No.	Year	Number of publications in Scopus [6]	Number of publications in Web of Science [7]
1	1996	2	3
2	1997	5	1
3	1998	5	5
4	1999	12	14
5	2000	23	25
6	2001	37	24
7	2002	30	25
8	2003	40	21
9	2004	39	18
10	2005	44	21
11	2006	40	27
12	2007	37	20
13	2008	45	24
14	2009	53	35
15	2010	82	39
16	2011	77	36
17	2012	54	22
18	2013	83	39
19	2014	90	59
20	2015	84	75
21	2016	141	102
22	2017	207	129

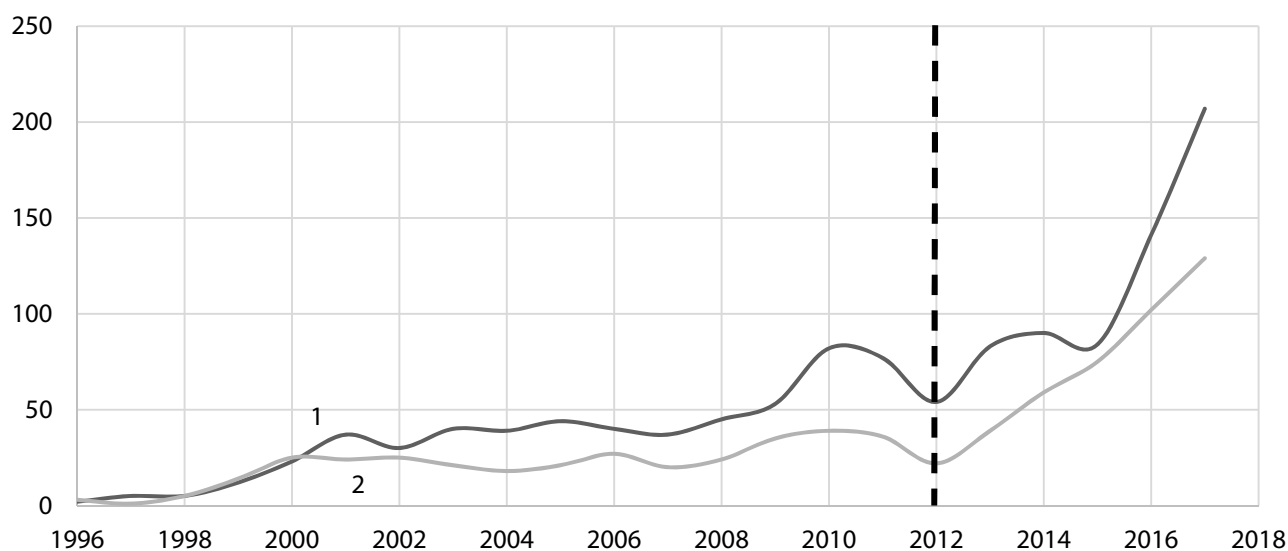


Fig. 1. Point of trend inflexion for a number of publications in scientific metric databases related to problems of digital economics. 1 — number of publications in Scopus, 2 — number of publications in Web of Science

synergy — induced by the use of common information channels, the wide availability of these channels and their efficiency, considerably higher possibility of receiving reliable and full information about rivals, about national and regional stock markets and business initiatives [12, p. 252].

Starting from the moment of “digital economics” term foundation, the substantial growth of scientific research volumes is observed, showing the importance of this matter for the effective solution of modern economics issues. Thus, from the moment of “digital economics” term introduction in 1995, in world-leading scientific metric databases (like Elsevier Scopus, Clarivate Analytics Web of Science), a substantial growth of a number of scientific publications related to this problematics is observed. This growth is shown in Table 1 in a structured form.

As the data in Table 1 shows, both scientific metric databases show substantial increase in scientific studies over the last two years as compared to earlier periods. This increase is visually presented in Figure 1.

Network effects, on one hand, express specific effects resulting from ICT implementation, e-business embodiment and interactions in global networks; on the other hand, facilitate the growth of total productivity in economics. These effects can be also obtained as a result of the employment of advanced methods for the implementation of hypercompetition, ICT business integration, coordination by networking, anticipatory programming and economic behavior of rivals and consumers management using hypercompetitive creative neuromarketing, management, logistics, etc.

New emerging neural network effects require specification and classification as new entities (elements) of intellectual network property. They need to get an adequate evaluation and be taken into account in the calculation of extended (with provision for integral-network benefits and effects) GNP. This implies the expansion of traditional national accounting system by means of inclusion of new integrative-distributed polyfunctional neural network effects into it, as well as necessity to correct (increase) GNP valuation by their amount (among other things, by amount of specified rights for new neural network proprietary articles valuation) [13, p. 90, 98–104].

In accordance with last studies, digital economics today has capitalization of about three trillion dollars. This is about 30 % of S&P 500, six times exceeding an annual trading deficit of the USA, exceeding the Gross Domestic Product of the United Kingdom. At that, this capitalization has been created over the last 20 years (from the moment of Internet launch). The majority of studies recognize that digital economics growth has widely spread over the whole economic sector.

In some studies, various attempts to categorize the extent of influence on traditional sectors were undertaken. For instance, in the Boston Consulting Group's study, "four waves of changes that cover consumer goods and retail business" [14] have been considered. Telstra, leading Australian provider of telecommunication services, denotes that under conditions of the digital economy, the competition will become more global and more intensive.

Taking into consideration the wide influence of digital economy factors, companies with traditional economic model [15, p. 153–156] actively assess the ways of responding to changes caused by digital economics. Banks are trying to implement innovations and employ digital tools for the improvement of their traditional business. Governments invest in infrastructure. For instance, Australian national broadband network has been implemented by the government of Australia in order to provide 93 % of the population with broadband available data transfer at a rate up to 1 GB/s within ten years. This confirms government interest in ensuring conformity between technological infrastructure and changing economical paradigm [16, p. 1220].

In Russia, the development of the digital economy is determined at the national level in accordance with "Digital Economics of the Russian Federation" (decree of RF government of July 28, 2017 No. 1632-r) government program approved by the Russian Federation government in July 2017. This document is determinative for the formation of goals and objectives for effective digital economy management at all levels of state authority.

One of the key provisions of this document stipulates the achievement of a certain level of informational and telecommunication infrastructure equipment necessary to provide an increase in the efficiency of regional information space management under conditions of the digital economy. Studies conducted by the authors [17, p. 359] have shown that these issues are of particular importance as their solution determines not only efficiency of governmental authorities but also self-consciousness of specific region population, its satisfaction with the quality of services rendering, level of support for actions of government authorities.

Data and Methods

A study [18, p. 105] has proven that in the course of convergence of NBIC (nano-, info-, bio-, cogni-types) industry sectors information spaces a synergistic effect appears due to their mutual penetration, and can then be calculated in volume terms by the following formula:

$$\Delta S = nk^4, \quad (1)$$

where k is a number of information systems in a cluster; n is a number of clusters.

This synergistic effect also has an economical component. At that, the value of economic effect is calculated as follows:

$$nS = \sum_{i=1}^k \text{Serv}_i \times x_i, \quad (2)$$

where x_i is the value of specific weight of service in information space cluster; Serv_i is the value of expenditures connected with specific service implementation. In the case of limited amount of financing, it is calculated as aggregate budget for informatization to cumulative volume of realized services ratio.

In the economics-related literature, synergistic and economic effects of regional information spaces convergence under the conditions of economic paradigm transformations and transfer to the sixth technological mode have been discussed [19, p. 22]. B. Koka and T. Prescott have established it in their study that company's involvement in the network of innovation interaction creates a company's value drivers as it provides substantial advantages in the process of company value buildup. These advantages are measured by three parameters: information amount, variety and richness [20].

It should be noted that under digital neural network economics, to build a technological infrastructure, it is necessary to take into account the amount, variety and richness of information, as well as synergistic convergent-network effects, in order to ensure integration and generation of knowledge based on digitalizing of economic operators flows.

Considering knowledge generation through information spaces one should apply the classical model of knowledge quantity evaluation by means of entropy level recession.

Claude Shannon, the founder of information theory, had introduced in 1948 the concept of "entropy" as an average of "information content" in a message, measured in bits (binary digits) [21, p. 379–423, 623–656]. Herewith, the term "information" has been initially introduced by Ralph Hartley in his article of 1928, "Transmission of Information" in which he studied information in technical terms as a measurable value reflecting the ability of a receiver to identify sequence of symbols transmitted by sender (without taking into account meaning or semantic contents of these symbols). Hartley's formula for information [22, p. 535–563] is as follows:

$$I = \log S^n = n \log S, \quad (3)$$

where S is the quantity of available symbols; n is the quantity of symbols in transmission. Information I is measured by decimal values also referred to as Hartley units.

The theory of information is a mathematical theory mainly related to coding and decoding. Its primary mathematical tools are the theory of probability and statistics. The Shannon's formula for entropy is as follows:

$$H(X) = -\sum_{k=1}^n p_k \log_2 p_k, \quad (4)$$

where $p_k = p(x_k)$ are discrete probabilities of random process (a message) X with possible values of x_1, x_2, \dots, x_n , which express probabilities of specific message transmission. $H(X)$ is the measure of information quantity contained in transmitted message.

Classical studies in the field of economic informatics define knowledge as processed information, recorded and proven in practice, that can be used and reused for decision-making. Knowledge is the kind of information stored in a knowledge base and representing an expert's knowledge in the specific area of expertise. Knowledge is intellectual capital [23, p. 208].

Model

With account to discussed features of information space development, it is practical to elaborate a conceptual model of convergence using entropic approach to management of knowledge processed in converged regional information spaces. Inter alia, considering the structure of information space of St. Petersburg executive bodies of state authorities, relying on number of modules in information systems based on data from Registry of state information systems of St. Petersburg⁵, it is possible to identify groups from clusters of information systems having similar features forming synergetic effects

⁵ Saint Petersburg Information Systems Register. Retrieved from: <https://reestr-gis.spb.ru/rgis/#main> (date of access: 23.04.2018). (In Russ.)

resulting from interaction. Thus, taking into account the entropic approach and with regard to (1) and (4), the specific entropy of cluster under synergetic effect in the process convergence will be calculated as follows:

$$H(X)/\Delta S = -\sum_{k=1}^n p_k \log_2 p_k / nk^4, \quad (5)$$

Using this formula, let us calculate the values of following metrics for information system clusters in terms of following values and ranges of parameters:

- average number of modules in the system: 30;
- number of systems in the cluster: 1, ..., 24;
- number of clusters: 1, ..., 3.

In the course of three-dimensional modeling, with its results shown in Figure 2, a surface was obtained that characterizes substantial decrease in specific entropy of the cluster with regard to synergetic effect in the process convergence. This model characterizes changes of entropy for clusters of information systems with the most characteristic parameters based on the Registry of state information systems of St. Petersburg in terms of quantity of modules, general typology and functionality. Presented values cover ranges of metrics characterizing currently functioning real information systems of a region. Thus, it may be concluded that the model obtained is relevant and reliable, and its results allow us to get an idea of real features of regional information space structure.

Resulting model allows to make conclusions about the decrease in specific entropy of information systems clusters in regional information space, while the developed methodological base allows to use

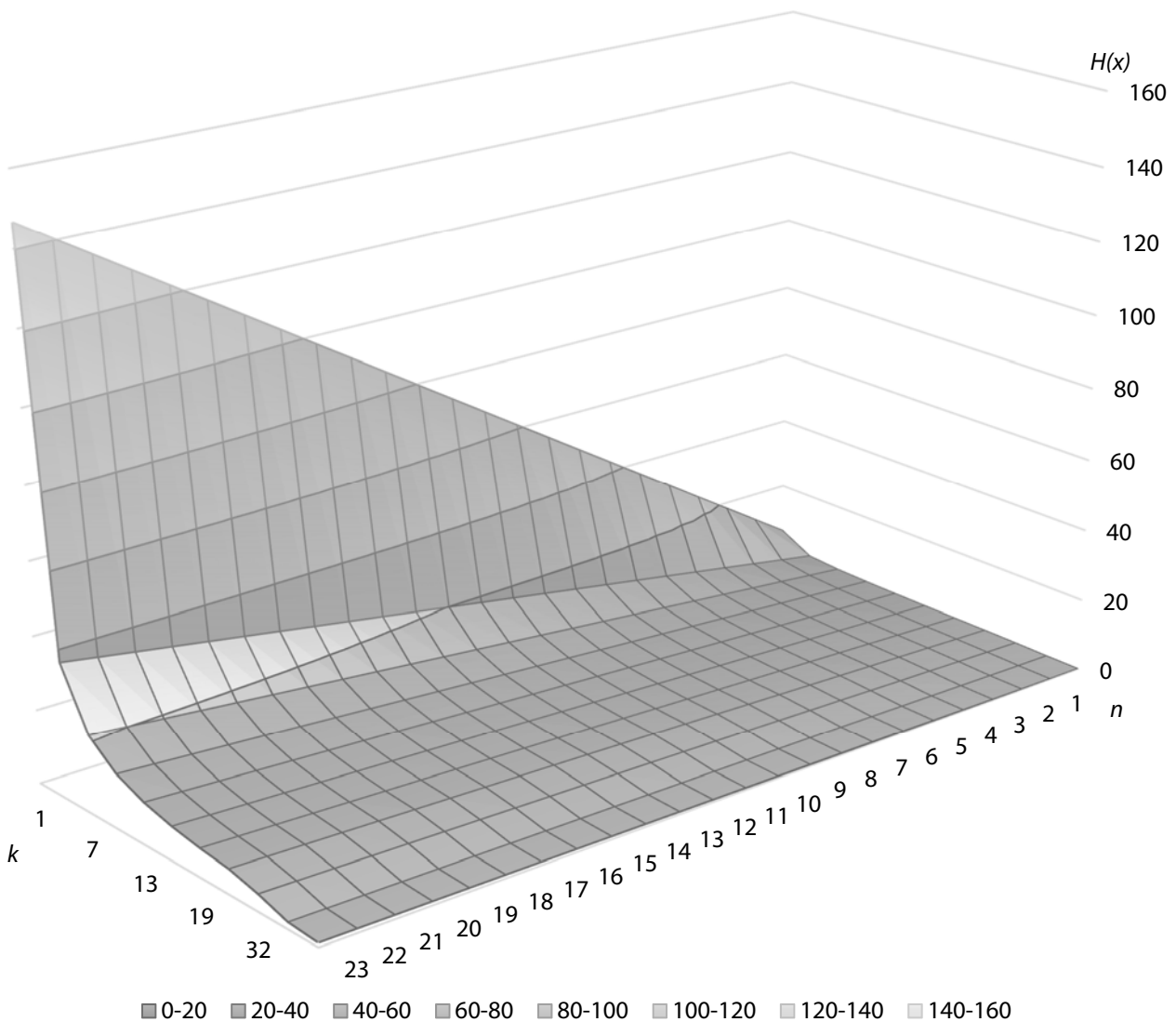


Fig. 2. Specific entropy of St. Petersburg regional information space clusters with regard to synergetic effects

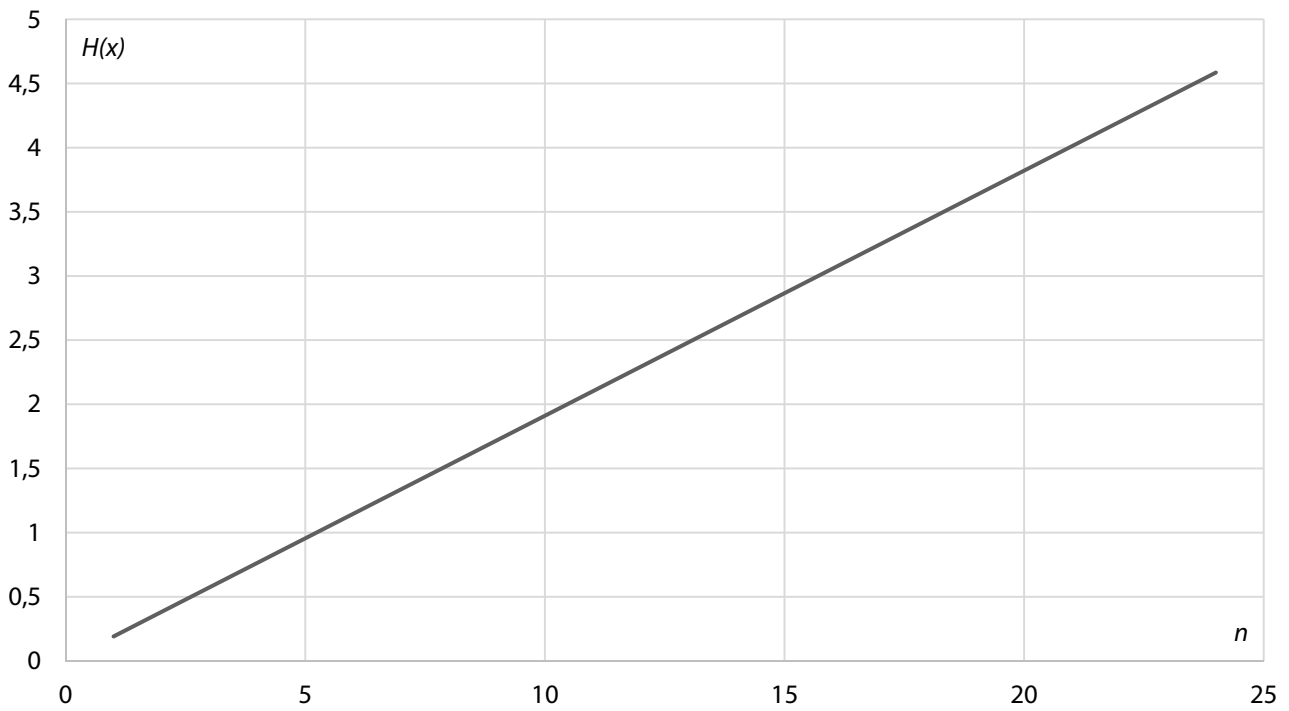


Fig. 3. Linear growth of entropy in cluster with the number of systems increasing

this model to manage convergence processes in the course of regional informatization management under conditions of the digital economy.

Results

It can be concluded that the synergetic effects of convergence arising under conditions of digital economics induce a decrease in the entropy of regional information space. Specified features can be quantitatively evaluated in the process of entropy calculation in the course of consideration of obtained model features presented below.

Inter alia, when a number of systems in cluster increases, the entropy rises, at that its growth is linear as shown in Figure 3:

Herewith, it should be noted that during convergence not growth but lowering of entropy is observed while its behavior is decaying as can be seen from Figure 4 (the calculation is executed for 2 clusters of systems):

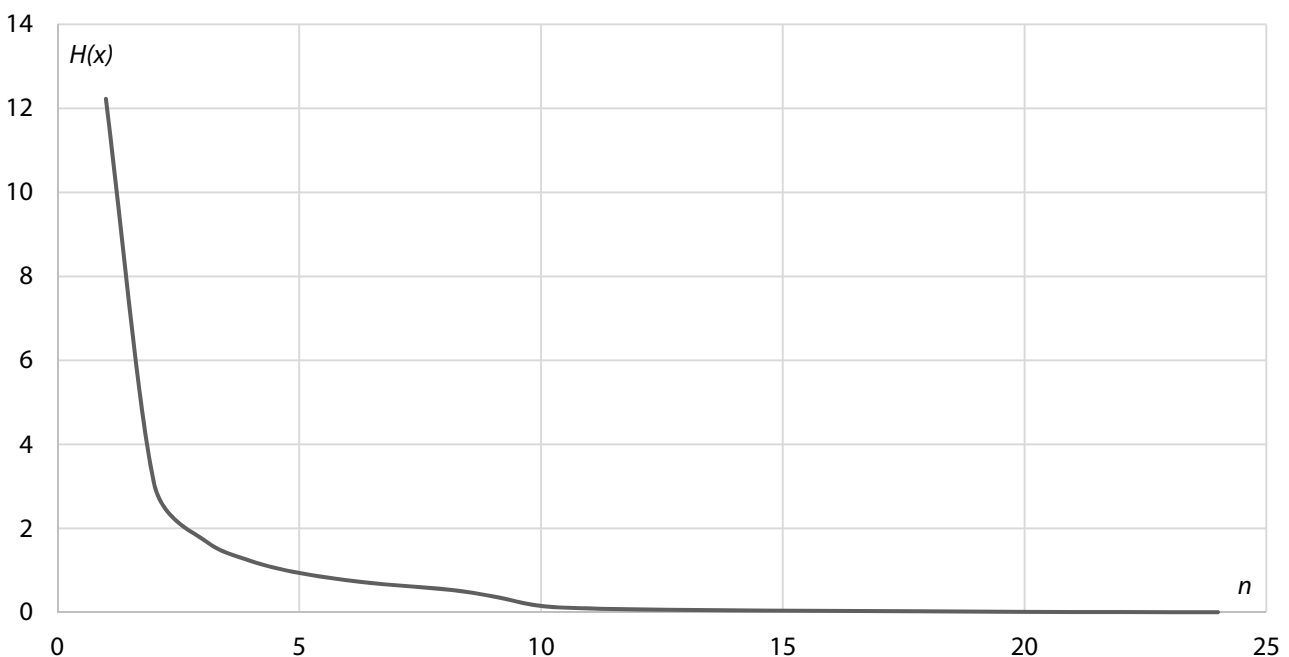


Fig. 4. Decaying entropy lowering during convergence

Specified features allow to numerically define identified convergence effects and evaluate the influence of existent structural transformations of the economic system on regional information space in terms of its management efficiency enhancement. Herewith, identified entropy lowering occurring in the course of these processes allows to conclude on the enhancement of efficiency of regional informatization processes management.

Additionally, as the quantity of converged clusters of information spaces increases, the entropy decrease speed in them also intensifies. Thus, the more information systems are involved in convergence processes existent during transfer to digital economics, the more significant entropy decrease will be, and, as a consequence, enhancement of corresponding industry economic system structures performance.

It is important to note the necessity of regional informatization governing bodies participation in ongoing changes of economic system and their support of ongoing processes at all levels of management. These actions should be carried out on regular basis to improve indicators of region development at the federal level, and under conditions of the digital economy when borders between states become penetrable—in international information-economic space as well.

Thus, in modern digital neural network economics, a whole class of brand new neural network (socio-neuromorphic) effects appears. In this context, a set of complex problems arises. First of all, the problem of determination, specification, evaluation of and accounting for various neural network effects and their consideration in extended GDP structure appears. This problem requires the development of new methodological and methodical approaches. Secondly, it is necessary to develop theory and methods for determination of synergetic effect from the convergence of local, regional and national information spaces into integrated information space of global digital neural network economics.

In the process of the development of methods for integral evaluation and measuring of various network effects and network benefits arising in the complex information system of network type, it is necessary to evaluate and consider following components:

- number of elements, quantity of information, richness of information and number of connections;
- nature and method of connections in the network;
- level, type, structural and functional organization (architecture) of networks;
- quality and measure of internal informational connections between elements and their functions within system;
- target development dominant of this system itself;
- entropy-synergy balance of given system.

Similarly, the degree of involvement or non-involvement of specified attributes can be investigated using neural network approach. The use of an interdisciplinary approach in this context is supposed to be the most effective [24, p. 430].

In modern digital economics, quantity and quality of information services are growing, the costs of connection to network and use of it are decreasing. The more users and connections are in a network, the more network synergetic effects it produces and the higher its integral value is.

Thus, the convergence of national, regional, local information spaces, platforms and segments of global digital neural network results in the appearance of a completely new class of synergetic effects.

Conclusion

The conducted investigation has shown that ongoing changes in the economic system affect the structural transformations of entire industry sectors including the sector of regional informatization. Previous studies have proven that in the course of industry economic paradigm change and transfer to the digital economy a convergence at the technological level appears, inducing emerging of synergetic effects. The present study based upon the background of previously identified regularities, information theory and global experience has identified decrease of entropy level of St. Petersburg regional information space clusters with regard to arising synergetic effects in the course of convergence in the digital economics. As part of the study, a model has been presented allowing to rationalize information space management system in terms of its management methods optimization and quantitative evaluation of achieved synergetic effects.

This study has practical significance for the development of management algorithms and effective management decision-making against the background of large-scale digitalization and network building inside the regional management structures.

Further perspectives for conducted research will be associated with universalization and scaling of the developed and suggested model in terms of developing an integrative-distributed soci-neuromorphic economic structure and management of regional information space with regard to transformational shifting of the Russian and world economy to digital neural network format and thus obtaining various neural network synergetic effects.

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