General Patterns of Formation of Digital Economy Ecosystems

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Keywords : digital economy ecosystems, network good, network effect, single sign-on technology, ERP systems, digital twins, predictive modeling ecosystems, hybrid digital ecosystems.

Abstract : Economic efficiency, competitiveness and success of economic entities operating in the industrial and agricultural markets today are determined by their flexibility and ability to adapt through the widespread use of information technology, the application of cognitive solutions, automation and computerization of all stages of industrial or agricultural production. The use of separate means of automation of production management in modern conditions is no longer able to adequately counter the problems and challenges facing market participants. It is obvious that the future belongs to complex solutions capable of integrating data coming from various sources, aggregating them, analyzing them in real time and giving the user recommendations for making management decisions. The article discusses the most general patterns of formation and functioning of digital business ecosystems used in the economic activities of industrial and agricultural formations. The conceptual and subject-object paradigm of digital ecosystems, their structural-functional and species differentiation are studied, and the most important concepts, from the point of view of sustainable development of the Russian economy, are analyzed and identified, allowing us to formulate the main directions of development of digital economy ecosystems in the near future and in the long term.

1 INTRODUCTION

One of the most obvious trends that determine modern trends in the global economy is the ever-increasing role of industry and inter-industry platforms for creating digital ecosystems used in the real sector of the economy. Such ecosystems, which have received the name "digital economy ecosystems" in the expert and scientific community, open up completely new opportunities for building business models, using innovative solutions, introducing high technologies, increasing the competitiveness of business and its adaptability to rapidly changing market conditions. Digital ecosystems have become such an important part of society, and the integration of a modern user into certain digital services and platforms is so great that disabling even individual digital services previously available to the user thanks to single sign-on technology can significantly affect the entire paradigm of socio-economic relations that link together various components of a comfortable existence of people and the normal functioning of the economy (Ivanov V.V. et al., 2019). It is obvious that within the framework of this trend, the use of industry platforms for building digital agribusiness ecosystems is one of the most pressing needs for the sustainable development of the Russian economy.

The ideology of the modern digital ecosystem includes the possibility of seamless (not requiring multiple authentications) integration of various digital services and platforms into a single digital space, in which, with the help of one registration, the user gets access to a virtually unlimited range of services and services that form the so-called "network good", which, in turn, opens up wide opportunities for scaling production, reducing costs and achieving a synergistic effect in the real sector of the economy (Digital Economy, 2023). Having emerged as a tool for providing the user with digital services and selling the network good, digital ecosystems are rapidly capturing the market, including its real segments where industrial and agricultural products are

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circulated. Single sign-on technology greatly simplifies the methods of consuming the network good by the end user, since now he or she does not need to use various services to obtain certain digital services or products: instead, you just need to log in to the corresponding digital ecosystem, which combines a variety of services provided both by the ecosystem itself and through external digital resources integrated into it.

In conducting this study, the authors focused their attention on the scientific and methodological analysis of the conceptual and subject-object paradigm of the institute of digital economy ecosystems, in the context of its structural-functional and implicative specificity in order to identify doctrinal and legal approaches to defining the concept of digital ecosystems, establishing criteria for their structuring and differentiation, and carrying out a comparative analysis of user and corporate ecosystems, including digital ecosystems created using state information resources and adapted to the needs of the digital economy.

The theoretical, methodological and empirical basis of this study is formed by the objective laws of socio- economic development of society, conceptual postulates and scientific and practical definitions formulated by foreign and domestic researchers on the problems of digital ecosystems and their integration into technological chains of industrial and agricultural production. To achieve the goal and objectives set by the authors of this study, a set of empirical, experimental and theoretical methods and techniques of economic research was used.

2 DIGITAL ECOSYSTEMS: BASIC CONCEPTS, CRITERIA, RELATIONSHIPS

Despite the rapid spread of digital ecosystems in both the socio-cultural and economic spheres of society, Russian science has not yet developed a unified concept of this institution of the digital economy. The term "digital ecosystem" or "digital economy ecosystem" often refers to concepts that are quite different in their semantic content and functional load. Moreover, in the established IT terminology, the concept of a digital ecosystem still does not have an unambiguous equivalent due to the fact that this phenomenon itself is divided into two forms that are quite different in their internal content. Firstly, these are intra-company (corporate) ecosystems, intended primarily for highly specialized use by corporation employees and the organization of business processes within the company. And secondly, these are external (public) ecosystems, intended for working with consumers of digital services. In addition, there are certain difficulties with the object-subject structuring of digital economy ecosystems in terms of their classification into certain sectors of economic activity, socio-economic orientation, regulatory legitimation, methods of integration with external services, target audience, tasks they solve, etc. Thus, there is an urgent need for a detailed scientific study of existing and prospective digital ecosystems in their unity and diversity, as well as a subject-sector analysis of digital business ecosystems in the context of their practical use in the real sector of the Russian agricultural economy.

The methodological and theoretical foundations for the analysis of ecosystems as a separate object of study in economic science, their genesis and influence on the development of the world economy were laid by James F. Moore in his work “Predators and Prey: The New Ecology of Competition”, published in 1993 in the Harvard Business Review (James F. Moore, 1993). A significant contribution to the development of the theory of digital ecosystems of modern business was made in the works of Michael Jacobides , Carmello Chenamo , Anabel Gower (MG Jacobides and etc. , 2018), James Melsa (Sage E.P., 1974), etc. Among domestic researchers of digital ecosystems, the works of E.V. Vasilyeva, B.B. Slavin (Digital Platforms, 2024), N.N. Bakhtadze (Suleikin A.S. et al., 2019), A.L. Bunich, etc. can be distinguished.

In modern Russian economic science, the most common approach to defining the concept of a "digital ecosystem" is a scientific doctrine that considers a digital ecosystem as "a complex of electronic platforms that integrate a full range of data on the dynamics of information flows and the potential for digital development of various spheres of human socio-economic activity" (Digital Ecosystems, 2022). This definition is essentially "doctrinal", since it reflects the views of only a certain number of researchers within a certain doctrine. It should be noted that there are other theoretical and scientific-methodological approaches to the terminological concept of digital ecosystems. For example, a number of scientists express the opinion that a digital ecosystem is a certain kind of "digital space in which many services of a company or several partner participants function seamlessly , the integration between which allows you to manage user behavior, achieve maximum speed and transparency of processes, identify problems and points of

improvement in different business areas of activity" (Popova, L.V., 2023). It should be noted that in the Russian Federation there is a legal definition of the concept of "digital economy ecosystem", contained in the Decree of the President of the Russian Federation of 09.05.2017 No. 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030". According to this regulatory act, the digital economy ecosystem is "a partnership of organizations that ensures the constant interaction of their technological platforms, applied Internet services, analytical systems, information systems of government bodies of the Russian Federation, organizations and citizens" (On the Development Strategy, 2017).

Most researchers of the issues of interest to us recognize the fact that a digital business ecosystem (regardless of the specifics of the product being manufactured, its quality and consumer properties) by the very fact of its existence provides its owner with opportunities to achieve competitive advantages, since it creates favorable conditions for the implementation of innovative and digital solutions, optimization of production processes and enterprise resource management, establishing partnerships with suppliers and consumers of a digital product, and much more (Filimonov O. I. et al., 2021). However, to realize these advantages and activate the so-called “network effect”, the architecture of a modern digital business ecosystem must meet certain requirements, namely: be as focused as possible on user needs; have a single sign-on technology (Single sign-on technology). Sign-On); have the ability to collect and process user data; have the ability to automate repetitive actions; be continuously updated and optimized, be global in nature, be flexible and easily adaptable to changing external conditions (Digital agriculture , 2020; PK Senyo and etc , 2019).

As the experience of implementing digital business ecosystems in the world's leading economies shows, the structure of a modern digital ecosystem should include the following elements (consorts):

- a central vendor company that is the owner of the ecosystem or the developer of software for its creation;
- economic agents that are in partnership or client relationships with a given business ecosystem;
- a jointly created good (product, service), the production of which is possible only within the framework of a business ecosystem.

2.1 Focus on user needs

The relevance of this criterion is due to the need to achieve an economic effect from the use of a digital ecosystem, regardless of the network or real good produced with its help. When creating a new ecosystem that offers the user a particular range of digital services or services, it is necessary to take into account the user's needs for the proposed digital product or service as much as possible. Consequently, the main goal facing the owner of the ecosystem is the maximum and fairly rapid increase in the number of clients to a level at which the usefulness of the offered services, services and products will increase due to the network effect. Of course, rapid expansion of the client base is more typical for user ecosystems, since the usefulness of a digital product is greater, the wider the circle of users involved in its consumption and promotion. The most typical example of this approach is the YouTube service, where the usefulness of the offered product increases proportionally to the growth of its consumption. Corporate ecosystems are characterized by a slightly different type of user orientation, which manifests itself in the ability to provide the user with access to the source code, or the creation of object-oriented programming environments to maximize the adaptation of the ecosystem's interface and functionality to the needs of a specific user or partner (Darvish & Kidd , 2021).

An important role in understanding the user-oriented nature of a digital ecosystem is played by the cost structure of network goods, mediated by the network effect, which manifests itself more intensely, the wider the user coverage of the ecosystem. As the practice of using digital ecosystems shows, the owner of the ecosystem (the manufacturer of the digital product) will have to bear the main costs at the initial stage (development and implementation of software, obtaining patents, trademarks, know-how, etc.). In the future, only copying and replication is carried out, the costs of which are negligible compared to the initial investment. At the same time, large manufacturers will not be interested in monopolizing the market by eliminating competitors, but, on the contrary, are forced to actively involve small and medium-sized manufacturers in the replication process in order to maximize the number of ecosystem participants. Graphically, the costs of producing a network good can be represented as a dependence shown in Figure 1.

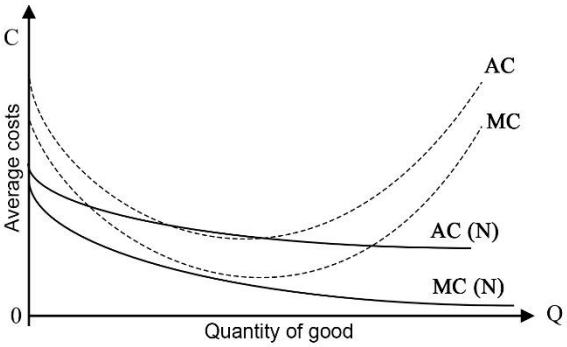

Figure 1: Costs of producing a network good.

2.2 Single Sign-On (SSO) Technology

Single sign-on technology provides the ability to work under a single account in many digital services. A characteristic feature of a modern digital ecosystem is the ability to log in to various services with one login and password without re-authenticating the user. One of the problems of modern digital ecosystems remains a secure algorithm for user verification and authentication. Today, the SSO standard of most user digital ecosystems is the procedure for establishing a trust relationship between the service provider and the access control system by exchanging a digital certificate between them. In this case, the certificate acts as an identifier containing encrypted information sent by the access control system to the service provider. This allows the service provider to verify the source of the information sent and record the user's identification data, which take the form of tokens containing user information: e- mail , phone number, identification number or username. When using the SSO algorithm for login, the authorization procedure is usually an exchange procedure between the service provider and the access provision system of the certificate-token type. Upon receiving a notification of a user logging into the application (on the ecosystem site), the service provider sends a token containing user information (e- mail , personal ID, username, etc.) to the access management system as part of a user authentication request. After receiving and verifying the token, the access management system must check whether the user has already been authorized in the system. If so, access will be granted immediately, and if not, the user will be asked to go through the authentication procedure by entering a password (PIN code, biometric data, or another authentication method). If the SSO system approves the identification data, the token will be returned to the service provider as confirmation of successful user authentication (Fig. 2)

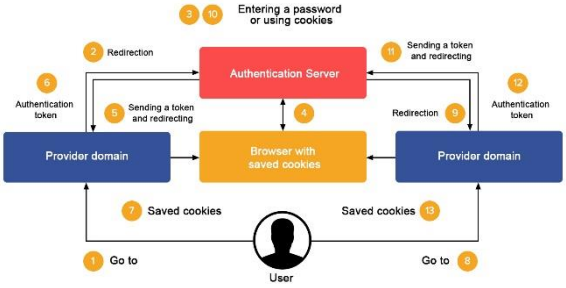

Figure 2: Standard SSO authentication scheme.

The main element of this type of authentication is the level of "trust relations" between the service provider and the ecosystem access management system. The main disadvantage of the SSO system is the need to establish a certain level of security when using trust relations. Security issues are relevant during seamless integration of external services and resources, since it is also necessary to establish trust relations with each of them, the security level of which must be at least no lower than that used during the initial login setup.

2.3 Collection of data about and for the user

The most important resource, the possession of which gives a decisive advantage in the competitive struggle, is information. Regardless of the field of activity, industry specifics, business model or other factors, the advantage is gained by those who have timely, relevant and reliable information. Thus, the most relevant is the platform integration of services that has the ability to collect, summarize, analyze and systematize information about consumers of digital services or services, capable of predicting customer requests based on this data and offering customers, based on such predictive modeling, exactly the digital or real product that best meets the needs of users. Collecting information about the user allows not only to predict consumer requests, but also to model user behavior in a certain way using social engineering technologies based on the data available in the ecosystem, thus contributing to the growth of sales volumes and increasing the usefulness of the product offered by the company.

Modern business ecosystems offer a very wide range of services in the field of collecting and analyzing user data and for the user, and such services can be provided to the user both through platforms integrated into global user ecosystems and on the basis of paid specialized solutions offering a wide

range of digital tools for organizing the collection and analysis of user data. The former include solutions such as Google Analytics, Yandex Metrica and some others. As for paid specialized platforms for collecting, analyzing and managing data, at the moment the number of such services is already so great that their listing alone would go far beyond the scope of this study. At the moment, almost all major software manufacturers for organizing digital business ecosystems offer their clients a wide range of software products for collecting and analyzing user data.

One of the most developed, but at the same time accessible to the user, data collection systems is the platform solution from Google "Google Analytics 4". The service is available on a conditionally free basis and allows you to:

1. analytics of user behavior on an Internet resource (the behavior of all users who visited the site is analyzed based on a given algorithm of the sequence of actions);

2. remarketing: organizing a system of notification for a user who has visited an Internet resource, with the development of an advertising offer based on his views and preferences, taking into account the group differentiation of users depending on his average check on this resource;

3. a developed system of customer services, from tracking the sequence of user views of goods or sections of the site to providing him with relevant recommendations on the purchase of certain goods, services or services;

4. data integration between CRM systems and Google Analytics (a paid service for users of business ecosystems built on Google partner platforms). The user interface of the Google Analytics 4 system is shown in Fig. 3.

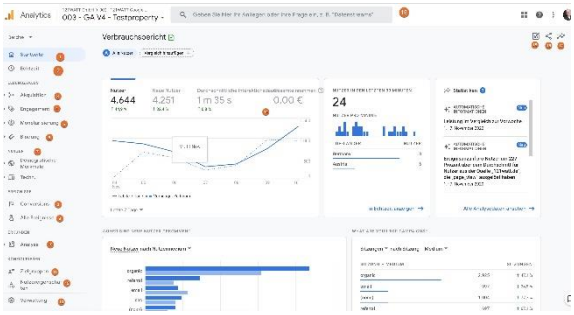

Figure 3: Client ID data statistics in Google Analytics 4.

2.4 Optimization and update

The ability of the software, on the basis of which the digital ecosystem is built, to function effectively and maintain the continuous operability of all its services, providing the user with the most convenient, simple and functional product, equipped with an intuitive interface, is determined by such a concept as "usability". The usability of a modern digital ecosystem directly depends on its optimization and continuously updated software and functional shell, the update of which is a continuous, never-ending process, involving huge resources, the work of programmers, beta testers, specialists in web design, animation, etc. For a modern digital ecosystem, the competent organization of its internal architecture and integration turns into the most important competitive advantage, since the simplicity and ease of use of the ecosystem is almost the main criterion when choosing a supplier of electronic services by the consumer.

One of the most popular digital platforms for building industry digital business ecosystems in the modern Russian market is the ready-made solution from 1C "1C: ERP Enterprise Management 2". This software product is a universal tool for building a comprehensive integrated management system for any enterprise, regardless of industry affiliation, business specifics, form of ownership and organizational and legal form. The ERP system from 1C implements a comprehensive approach to business management, combining flexibility of configuration, ease of use and significant economic effect. This solution is updated monthly (and sometimes more frequently), in particular, in the latest version of the product, almost all software components were updated (Table 1).

Table 1: List of updates 1C: ERP Enterprise Management 2. ver. 2.5.16.61.

Version number	New in the version	
2.5.16.61	Budget	Algorithm for the transition to obtaining actual data based on balance sheet register data
		Analysis of discrepancies in the collection of facts based on balance sheet register data from the collection of data based on turnover register data
	Sales	Setting up payment via SBP in wholesale documents
		Formation of a payment link for payment
		Registration of payment receipt via SBP
		Refund of payment under SBP
		Downloading a bank statement with payments via SBP
		Bank report on acquiring

		Printing an invoice with a QR code for payment of the SBP
	Warehouse and delivery	Shipment from a warehouse with address storage
	Production	Simplified description of intermediate semi-finished products in resource specifications
	Regulated accounting	Balance sheet reform in the presence of separate divisions
		Setting up grouping of types of assets and liabilities for accounting according to PBU 18
	Salary and personnel	Terms and frequency of notification of personal income tax in 2024
	Management Cost Accounting	Distribution of expenses to financial result (current period expenses)
	Financial accounting	Movement of other assets and liabilities
		Printing certificates
		Setting up the frequency of closing income and expense accounts
		Adding the ability to select the accounting object "Other assets and liabilities"
	Service and integration	Standard subsystems
		Integration with 1C: Document flow
		Working in the cloud service 1 C Frech
		Library user support online
		Document recognition library etc.

2.5 Global nature and adaptability

Despite the current important geopolitical events related to the redistribution of economic and political influence in the world, globalization remains the most important trend in the creation and operation of digital economy ecosystems. The orientation of user digital ecosystems to the global market and the globalization of products and services offered within the ecosystem is determined by the need to maximize the use of the network effect. This means that an ecosystem that is not initially oriented toward expanding its coverage to the entire global world or most of it will not be competitive in the global market, since the services offered by this ecosystem, being localized within one state (or quasi-state entity), will not be able to compete in the digital market with companies that have global or transnational coverage. The rethinking of their role in the global division of labor, currently taking place in a number of states (the Russian Federation, China and some other countries), has led to these states taking measures to protect their national markets from the influence of global corporations. However, the low efficiency of these measures shows how difficult the process of breaking free from digital and network dependence is in the modern global economy. As the experience of states focused on protecting national economies from external influence shows, the digital services market depends very little on the adoption of protectionist measures. This is due to the fact that, already at their creation, all modern global digital ecosystems were built as platforms that assumed further scaling of the business and its distribution throughout the world or most of it (Digital Platforms, 2024).

Flexibility and the ability to adapt to both market requirements and emerging user needs in the context of total digitalization is becoming the most important factor influencing the choice of a particular digital ecosystem and its use both for the purpose of receiving a set of digital services and for participating in the creation of the digital product itself as a developer, partner, franchisee, etc. The principle of open architecture underlies most modern digital ecosystems used for production management and integrated business management, which initially implies the possibility of seamless integration with external resources, adding new services aimed at satisfying emerging user requests or market requirements. This means that the principles of building modern digital economy ecosystems should be able not only to meet changing user requirements as quickly as possible, but also, if possible, anticipate these requirements.

3 THEORETICAL AND METHODOLOGICAL ASPECTS OF SPECIES DIFFERENTIATION OF DIGITAL ECOSYSTEMS

As already mentioned, the species differentiation of modern digital ecosystems is represented by intra-corporate and user ecosystems. This does not mean that both do not have common properties and characteristics - on the contrary, the trends in the development of digital economy ecosystems are such that the differences between these two types will become increasingly conditional in the near future. However, at the moment, it still makes sense to draw a certain line between user and corporate ecosystems, or, as they are sometimes called in the scientific and expert community - internal and external ecosystems, since they have significant differences in their subject-object composition, purpose and target audience.

3.1 Intra-corporate digital ecosystems for predictive modeling

Most often, this type of digital ecosystem is developed by large IT companies focused on producing a digital product and promoting it through a network of partner companies. In most cases, the products manufactured by the aforementioned companies are not aimed at the consumer market, since their buyers are commercial (less often non-commercial) organizations: companies of various forms of ownership, firms, small and medium-sized entrepreneurs, farms, etc. They also become both users and partners of the digital ecosystem created by the software developer. In the future, as the digital product is implemented at the enterprise, the internal corporate ecosystem is integrated into the vendor's ecosystem using API technology in order to provide partner firms with access to the vendor's digital resources: databases, cloud services, hardware and software resources, etc. In turn, having integrated into the vendor's ecosystem, the internal corporate ecosystem itself becomes a gateway for connecting other partners, services, digital platforms, etc. In other words, the subject paradigm of such ecosystems is not limited to just client users or partner users. As we can see, potentially corporate ecosystems are no less oriented toward globalization than user ecosystems, although this globalization has a narrow industry focus (F. Nachira , and etc , 2007). In the Russian market of software for building corporate ecosystems, the largest players are such companies as 1C, AFK Sistema, MCST. Among the companies that have achieved serious success in developing their internal (corporate) ecosystems, the leaders are Gazprom, Rosneft, Rostec, Sber, Rosselkhozbank, etc. And many other modern Russian companies use in their production and business activities quite functional and modern digital ecosystems built using ERP technology (enterprise resource These systems allow you to effectively manage production processes, interact with customers, conclude electronic contracts, provide pre- and post-sales service for your product, and much more .

3.2. User (external) ecosystems

Custom, in other words, focused on the widest possible coverage of the client base, digital ecosystems are globalized Internet platforms that grew out of once small, most often postal services, which initially offered their users a very limited range of digital services: email, instant messaging or file sharing. However, today these services have become transnational giants that control more than 90% of the digital services market. Companies such as Google, Microsoft, Amazon, Apple have a capitalization that significantly exceeds similar indicators of companies operating in the commodity and financial markets. The range of services offered by such a company as Google, for example, covers almost all aspects of modern human life: from electronic communication to solving problems in the field of cognitive technologies, business planning and creating their own user ecosystems. In the Russian segment of the Internet, the undisputed leader in both the client base and the number of services provided is Yandex, which offers its clients no less a wide range of services than Google. The company's strategy includes not only the development of its user ecosystem, but also active cooperation with corporate clients, including in the context of creating corporate business ecosystems based on Yandex services. In particular, among the paid services aimed at corporate clients there are such solutions as the speech synthesis and recognition service (Yandex SpeechKit), a cloud platform for creating your own digital services on the Yandex platform (Yandex Cloud) and much more.

3.3 Hybrid digital ecosystems

Ecosystems of this kind represent a combined approach that combines the features of both internal corporate and user solutions. Ecosystems of this kind are created with the aim of covering as broadly as possible business processes of an inter-industry nature, or within any one branch of the national economy, but with the most universal functionality that combines all stages of the production process, from purchasing operations, searching for suppliers and partners to selling products, working with clients and implementing post- and pre-sales service. In addition, hybrid ecosystems can also be aimed at solving any specific problems in a particular industry. The already mentioned ERP systems have certain features of a hybrid ecosystem, and in particular, 1C: Enterprise 8. ERP Agro-industrial complex can serve as an example of such an ecosystem (Ivanov V.V. et al., 2019).

Recently, there has been a noticeable increase in interest in the institute of digital ecosystems in the scientific and expert community. The main areas of scientific discussion are the issues of the genesis of ecosystems in biological and digital interpretation, the conceptual and subject-object paradigm of digital ecosystems, their structural and species differentiation, specificity, development prospects, as well as a number of other equally pressing issues of

modern scientific, theoretical and methodological understanding of this institution of the digital economy. One of the most controversial issues remains the problem of definition. As already noted in this study, the views of scientists on this issue vary greatly.

A number of researchers interpret the digital business ecosystem as “a set of platforms, Internet application services, analytical systems, government information systems, organizations and citizens of cooperating and competing firms offering related products and services” (H. Dong and etc. , 2007). Other experts define a digital ecosystem as “a distributed socio-technical system with the properties of adaptability, self-organization and sustainability, functioning in conditions of competition and cooperation between various subjects of this system, in which knowledge is exchanged for the evolutionary development of the system” (Popova L.V., 2023).

4 ECONOMIC EFFICIENCY OF DIGITAL ECOSYSTEMS OF SMALL AGRIBUSINESS

It should be noted that at the moment, researchers have not come to a consensus on the methodology for assessing the economic efficiency of using digital ecosystems in real production. The current state of affairs in economic science can be explained by a number of reasons, ranging from the difference in approaches to structuring digital ecosystems to the lack of unity in views on assessing quantitative and qualitative values by which economic efficiency can be assessed in this context. In addition, the Russian State Statistics Service does not conduct statistical monitoring at all for a number of indicators characterizing the level of digitalization, including the degree of use of digital economy ecosystems by economic entities . In the field of digitalization, published statistical data are sporadic, not systematized and do not reflect the desire of state statistical agencies to develop a single unified approach to identifying trends in the digital development of real sectors of the economy. In order to fill this gap, the authors of this study, within the framework of the implementation of the RSF grant, conducted a sociological survey of heads of peasant (farming) households and households of the population through a combined survey, during which respondents were asked to complete a questionnaire to identify the level of digital development of the MFF, as well as the presence of digital and innovative potential for technological transformation and integration into digital ecosystems.

The factor of sanctions, which were further developed in 2022, after the start of a special military operation, began to play a significant role in the development of the methodology for assessing the economic efficiency of digital ecosystems of small agribusiness. The introduction of bans and restrictions on access to a number of digital technologies and software by unfriendly states against Russia significantly changed the initial plans formulated by the Russian government in various programs and strategies for the development of agriculture. Therefore, when developing the author's methodology for a sociological survey of small agribusiness entities in the region, the factor of restrictions on access to digital and information services based on imported software was taken into account, and the potential ability of import substitution in the field of deploying digital platforms and services based on domestic software and element base was assessed. Respondents were asked questions aimed at identifying the level of computerization, the development of information and digital systems, the availability of broadband Internet, the use of software (including domestically developed programs), as well as the costs of implementing and using digital technologies. As the study showed, the largest part of expenses by small agricultural businesses is spent on purchasing or repairing computer and office equipment, while the costs of developing, purchasing, updating, and maintaining software are significantly lower. This may indicate, on the one hand, the presence of certain stereotypes in the mentality of Russian entrepreneurs who prefer to invest in fixed assets that have a material expression in the form of one or another object of information infrastructure, and on the other hand, the reluctance to spend money on purchasing licensed software, since there are quite functional pirated copies or other opportunities for using the said software.

To determine the numerical values of economic indicators as a result of the introduction of digital ecosystem elements into the economic activity of small agricultural forms, several farms located in the most promising natural and climatic zones of the Volgograd region were used. As a result of the studies, the necessary information was obtained on various parameters of the economic activity of the "smart farm", including: production volumes and the level of its profitability, climatic conditions, information and material flows, labor force movement, personnel qualification level,

infrastructure, as well as the architecture of the digital ecosystem elements used in a particular peasant (farm) farm. A detailed scientific analysis of the above economic indicators allows us to establish the dependence of certain segments of the regional agricultural structure on the level of their digitalization and potential readiness for integration into the digital ecosystems of the agro-industrial complex.

The authors solved the problem of identifying the interdependence of digital development on the main economic indicators of the economic activity of small agribusiness entities by introducing a special indicator of the level of digitalization - the "Index of Digital Development of the Industry" (IDD) as the sum of the given indices characterizing the degree of development of the digital infrastructure of the industry as a whole. Using this index, the team of authors developed the following mathematical model to identify the dependence of sustainable growth of the regional agro-industrial complex on the index of its digital development (1)

$$SD_t = DDI_t / DDI_{t-1} * \sum_{i=1}^{n} PI_{it} \quad (1)$$

where SD_t is a dimensionless indicator of sustainable growth over a period of time t ;

PI_{it} – production index of the i -th product for the time period t ;

DDI is a digital development index defined by formula 2:

$$DDI = \sum_{k=1}^{m} X_{k\,t} / X_{k\,t-1} \quad (2)$$

where Xk are the reduced indices characterizing the degree of development of the digital and innovative infrastructure of a particular sector of the regional economy.

In principle, various indicators from the following list can be used as such indices:

- production indices;
- investment activity index;
- indices of costs for the implementation and use of digital technologies;
- index of costs for carrying out scientific research and development;
- index of personnel readiness for digital transformation;
- index of innovation potential, etc.

This study used indices of production of the main types of agricultural products, as well as indices of costs for the implementation of digital technologies, but this list can be significantly expanded in the future.

Moreover, the final value of the IPI will be the more relevant, the greater the number of given indices X_k will be used for its calculation. It should be noted that in a number of previous works, the authors have already studied the methods for calculating such indices as the index of innovation potential of small agribusiness entities (IIP), as well as the index of sustainable development of the regional agro-industrial complex.

In conclusion, we note that the proposed mathematical model, without claiming absolute universality and applicability to all aspects of economic activity of business entities without exception, has a number of advantages, since it allows you to get a general idea of the readiness for digital transformation of certain entities of the regional agricultural structure, and also makes it possible to assess the dynamics of digital development of the industry and its readiness for integration into digital ecosystems of the agro-industrial complex. Numerical indicators of the ICR close to one will indicate the absence of positive dynamics of digital development, while negative values will mean digital stagnation in a particular segment of the regional agricultural structure. As shown by the calculations carried out in relation to the small agribusiness sector of the Volgograd region, the optimal value of the ICR for the progressive digital development of small farms and their integration into existing and prospective ecosystems of the digital agricultural economy is ICR $\geq$ 1.5. This value of the digital development index indicates the presence of sustainable growth in the main dynamic indicators of economic activity of small agribusiness entities, occurring against the background of their implementation of certain components of digital business ecosystems of the agricultural economy, which in turn guarantees seamless integration into existing or prospective ecosystems of the digital economy.

5 CONCLUSIONS

The conducted scientific analysis of the genesis of digital ecosystems, their subject-object composition and species differentiation allows us to conclude that in the scientific and methodological context, the digital ecosystem is one of the most relevant and discussed institutions of the digital economy, which is confirmed by a large number of studies in this area. The development of this scientific phenomenon is facilitated by the digital economy, acting as a kind of catalyst for the formation and development of digital

ecosystems, their varieties and interrelations. This, apparently, explains the extremely wide variety of approaches to the conceptual and terminological aspects of the institution of digital ecosystems. As a result of the analysis of many different definitions of the concept under study, the authors proposed their own concept of defining a digital ecosystem as "a set of technological platforms, applied Internet services, analytical and information systems created on the basis of a computer network infrastructure, possessing the properties of self-regulation, adaptability and sustainability for the purpose of joint production or promotion of a certain good, information exchange and evolutionary development of the system."

The relevance of building intra-corporate ecosystems based on industry digital platforms is determined by the technological, economic and environmental feasibility of integrating production process management, management, logistics, storage and sales of finished products into a single digital cluster using predictive models for processing large heterogeneous production data in real time. An ecosystem built in this way should not only ensure production process management, but also carry out predictive actions: based on the technology of cognitive digital twins, ensure the prediction of the behavior of the subject-object digital business model, ensuring advanced aggregation, analytics and systematization of the information collected by the company and offering its business partners and clients innovative solutions even before the need for them is realized by the latter.

ACKNOWLEDGEMENTS

The study was supported by the grant of the Russian Science Foundation No. 24-28-00066 “Formation of digital mechanisms for sustainable development of small agribusiness”, https :// rscf . ru / project /24-28-00066/.

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