"The impact of collaboration strategy in the field of innovation on the effectiveness of organizational structure of healthcare institutions"

AUTHORS	Tetiana Grynko ⓘD https://orcid.org/0000-0002-7882-4523
	ℝ https://publons.com/researcher/C-8756-2016/
	Tetiana Shevchenko
	Roman Pavlov ⓘD https://orcid.org/0000-0001-7629-2730
	ℝ https://publons.com/researcher/S-2421-2017/
	Vladyslav Shevchenko
	Dariusz Pawliszczy ⓘD https://orcid.org/0000-0003-1328-7891

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Tetiana Grynko, Doctor of Economics,
Professor, Oles Honchar Dnipro
National University, Dnipro, Ukraine.

Tetiana Shevchenko, Doctor of
Biological Sciences, Professor, Oles
Honchar Dnipro National University,
Dnipro, Ukraine.

Roman Pavlov, Ph.D. in Economics,
Associate Professor, Oles Honchar
Dnipro National University, Dnipro,
Ukraine. (Corresponding author)

Vladyslav Shevchenko, Ph.D. in
Economics, Oles Honchar Dnipro
National University, Dnipro, Ukraine.

Dariusz Pawliszczy, Ph.D. in
Economics, Mayor of Gromadka,
Poland.

Tetiana Grynko (Ukraine), **Tetiana Shevchenko** (Ukraine), **Roman Pavlov** (Ukraine), **Vladyslav Shevchenko** (Ukraine), **Dariusz Pawliszczy** (Poland)

THE IMPACT OF COLLABORATION STRATEGY IN THE FIELD OF INNOVATION ON THE EFFECTIVENESS OF ORGANIZATIONAL STRUCTURE OF HEALTHCARE INSTITUTIONS

Abstract

The need for innovative development of healthcare institutions is determined by the necessity to increase the efficiency of organizational processes based on the formation of new models of cooperation, which will make it possible to get access to new technologies and knowledge. The goal of the study is to determine the parameters of the impact of innovative open cooperation strategy and the strategy of innovative closed cooperation of healthcare institutions on the effectiveness of their organizational structure in the context of dissemination and the use of knowledge. Simulation modeling was applied to generate the most effective organizational management structure in the context of innovative cooperation and knowledge exchange within the organizational processes "Inside-out" and "Inside-in". It is substantiated that the strategies of innovative cooperation "Open Innovation/Closed Innovation" have a significant impact on the organizational structure of management of healthcare institutions in terms of the "degree of centralization" (Dc_i), "degree of mediation" (Di_i), and "degree of centralization of powers" (Dp_i). The values of the selected criteria range from 25,52% to 61,50% in the case of Di_i, and from 34,53% to 52,63% in the case of Dc_i, which indicates a higher efficiency of organizational knowledge exchange processes in healthcare institutions, which adhere to the Open Innovation strategy of innovative cooperation. Therefore, there are significant differences in the effectiveness of the management's organizational structure depending on the degree of openness of innovative cooperation of healthcare institutions. The strategy of innovative openness allows increasing the number and quality of connections in the context of knowledge exchange between the subjects (actors, agents) of the organizational structure (in a broad sense, considering internal and external levels of externality) of healthcare institutions, regardless of the distance between them and the level of similarity.

INTRODUCTION

The organizational and economic mechanism of a health care institution is a specific formation, which has, in addition to the general, some special functions and principles. Although the structure is standard (in comparison with other types of enterprises), its content and functioning has certain features that are determined by the non-monetary nature of services, the peculiarity of formation of the activities' economic parameters, the importance of personnel qualifications in the provision of services, innovative development, the use of advanced knowledge in the provision of innovative medical services, etc. It should be noted that health care institutions operate in a changing environment that encourages innovation in technology and service delivery. The increasing competition of services, the parameters of which

are of non-monetary nature, and cannot be quantitatively measured in any other way, determines the need to transform the structure of the organizational and economic mechanism taking into account innovative development and the value of knowledge as an asset.

The new organizational structure of a health care institution and the infrastructure that ensures its functioning should facilitate, first of all, their interaction in such a way that innovation and the quality of services constantly grow, the skills of personnel are improved and the total amount of technological knowledge increases. Interactions of this type can take the form of collaboration, mergers and acquisitions, licensing, patents, crowdsourcing, etc. Since 2003, the term used to encompass such practices is called Open Innovation (Chesbrough, 2003).

All these practices are characteristic of health care institutions, when independent experts and specialists from university centers are engaged to deliver technologies for the provision of relevant services (e.g. Velychko et al., 2018; Prokopenko & Omelyanenko, 2018; Chukhray & Mrykhina, 2020). Organizationally such clinical diagnostic laboratories and centers may not be a part of medical institutions. In addition, there are stable feedbacks when a healthcare institution expands the scope of its laboratories and centers, provides advanced training for specialists and promotes the innovative development of its partners. This vision of medical institutions' interaction can be summarized within two processes (Gassmann et al., 2009, 2010): "Inside-out" (valorization of internal concepts or knowledge of the organization) and "Outside-in" (search for ideas or skills outside the organization).

Since the middle of the twentieth century it has been known that the organizational structure and strategy of cooperation affect innovative capabilities of companies, organizations and institutions in different fields, in particular, healthcare institutions. Less formal and more organic organizational structures are more effective in the innovation dimension (especially in the context of knowledge creation and sharing) than bureaucratic types of organizational structures. The relevant scientific literature notes that the strategy of cooperation in the field of innovations affects the efficiency of organizational structure of the medical institution's management, but there is little substantiated evidence.

1. THEORETICAL BASIS

There are a number of approaches to economic and mathematical modeling of the organizational structure, in particular, in the context of innovation management. One can cite, first of all, the Bass model (1969) – one of the earliest and actively used ones, which makes it possible to model the adoption and distribution of an idea or product in social environment. There are many adaptations of this model in the context of innovations dissemination – Kiesling et al. (2011) provide an overview of the main results. However, most of these models relate to the dissemination or adoption of innovations in the marketplace.

Along with the Bass model (1969), scientists tried to give answers to the questions related to the modeling of organizational structure using other economic and mathematical models. Csaszar (2013) proposes a model of organization based on the ability to conduct research and to obtain profits. However, a simplified view of the decision making process is used regarding the likelihood of inaction error or an error committed by the decision-making committee. The error of doing nothing, for example, is seen as a missed opportunity for effective investment, while the error of doing it is seen as an inefficient investment of capital. Therefore, these errors affect the ability of companies to be symmetrical in decision making in the context of their organizational structure (e.g. Grynko et al., 2016). The Csaszar (2013) model uses a special way of representing the organizational structure – two extremes are considered when the structure can make decisions in a hierarchical or collegial manner. Visualization in the form of points is used to simplify the presentation of organizational structure, when each point represents one subject (actor, agent) of the organizational structure. Points are vertically aligned in a hierarchical structure, and horizontally aligned in a flat structure. For more

complex structures, points can form squares, rectangles, etc. (Csaszar 2013).

In the scientific literature, the influence of organizational structure on performance is considered in terms of the acquisition of skills, the performance of tasks or the ability to make decisions. An approach to economic and mathematical modeling offered by DeCanio et al. (2000) is one of the few ones, which consider the cost of information transfer in presenting the efficiency of organizational performance. A certain limitation of the mentioned model is the assumption of homogeneity of subjects (actors, agents). This means that the cost of communications between subjects (actors, agents) is the same for each of them, as well as the benefit from receiving innovations.

The skills of the subject (actor, agent) may not be fully transferred to the project. For example, Westergren and Holmström (2012) point out that the joint use of inter-organizational knowledge requires mutual trust, and maintaining trust is a way in which organizations can mitigate risk, which means that the role of trust in an organizational network is critical to Open Innovation. Argotel and Ingram (2000) also point to the need for trust, adding a human factor, believing that individuals must be adapted to work together and to receive information, otherwise there will be a loss of trust in the transfer of knowledge. Gulati (1995) explains that transaction costs will increase if two businesses do not trust each other, as true partners must strive for fair cost levels.

It has to be taken into account that transferring skills through a third party is not as effective as direct transfer (e.g. Yakobi, 2016; Sulistiawan & Rudiawarni, 2019), as information distortion can occur. This is seen in the context of the concept of asymmetric information, when there is a mismatch in the level of ownership of information between stakeholders in the buying and selling process (Akerlof, 1970). Pisano (2009) indicates that the search, observation and selection costs increase (and can become prohibitive) as the network grows larger. A similar view is present in the work of Ollila et al. (2016) regarding project management, which becomes more complex as the number of partners increases. Therefore, it is important to further deepen the understanding of

the organizational structure of healthcare institutions in the context of Open innovation.

Therefore, the implementation of simulation modeling of the formal organizational structure makes it possible to test the assumption about the influence of the innovative cooperation strategy (Open Innovation and Closed Innovation) on the effectiveness of organizational structure of healthcare institutions.

The environment can be considered as one of the main factors influencing the development of an enterprise, in particular an individual healthcare institution. Open innovation provides for a close and continuous link between the healthcare facility and the environment. Organizational aspects are important for the implementation of Open innovation in the activities of healthcare institutions.

Open Innovation has much in common with a systems approach in the sense that a healthcare institution can only develop in an environment consisting of a multitude of information that affects the organizational structure of an enterprise, its strategy and project management. Both approaches make it possible to form a high level of openness of the organizational and economic mechanism of an enterprise, to facilitate its adaptation to the changing conditions of economic environment and the ability to maintain internal stability. However, at the same time, a significant number of interactions are formed, which ensure the high efficiency of the institution's functioning and complicate the process of its management. This is especially true for the application of Open Innovation, which can generate new forms of interaction.

In this context, the main focus is on the study of Fillol (2004), who makes a similar comparison with learning organizations. Health care institutions can be easily attributed to this type of organizations, since the very nature of medical services provides for their added complexity and innovativeness, which lead to significant changes in the production and technological mechanism, and, consequently, determines changes in the entire organizational and economic mechanism. When developing a conceptual model for organ-

izing the management of a healthcare institution based on a systems approach, it is necessary to take into account three key variables (Steiner et al., 2012):

1. Environment. The Open Innovation paradigm envisions the openness of healthcare institutions and the blurring of their boundaries in order to attract external knowledge and skills of external actors in order to increase the ways of valorizing internal concepts and knowledge (Chesbrough, 2003). Therefore, the environment in which a health care institution operates is key to its survival and development. The environment of a health care institution is formed by independent clinical diagnostic centers, consultation centers, clinical diagnostic laboratories, educational institutions (e.g. O. Velychko & L. Velychko, 2018), other health care institutions that perform additional functions or provide such services that the institution cannot.

2. The organizational structure of a health care institution is considered as a set of subjects that form a certain structure of relationships. The components of the medical institution's organizational structure include projects and subjects (actors, agents).

3. Strategy. For healthcare institutions the subjects (actors, agents) will define goals and take appropriate measures to achieve such goals within the existing strategy. For health care institutions based on a project-based approach, these will be projects that contribute to the achievement of the set goals. A strategy that fosters collaboration can practice Open Innovation and implement activities that promote the exchange of information and skills.

According to the contingency theory, enterprises must adapt to their environment by considering information changes (Burns & Stalker, 2001). Such information elements are called influencing factors. It is necessary to control such factors of influence to achieve the goals of health care institutions. Every organizational project has a skill capital that makes it possible to control influencing factors. If the factor is not controlled due to lack of skills, then it is necessary to master the skills to

control them. Keeping the influencing factor under control makes it possible to consider its features and limitations for the project.

Controlling the influencing factor with one skill (or multiple skills) is a matching of two concepts. In the context of Open Innovation, matching can be used to refer to the outcome of a combination of high level skill and influencing factors (Steiner et al., 2014). That fits into the concept of dynamic capabilities, which links an institution's ability to create new skills to accommodate changes in the environment (Teece, 2007, 2019).

Everything that comes out of the environment is information that influences health care institutions, in particular: the factor of circumstances (e.g. Bahemia et al., 2017), environmental factors (e.g. Kozmenko & Volkovets, 2014; Kuznetsova et al., 2017), contextual variables (e.g. Bahemia et al., 2018), cultural and legal (e.g. Agustini et al., 2019; Pavlova et al., 2019). Therefore, the factors influencing projects can be considered as "factors of influence" (Steiner et al., 2012).

From the standpoint of Open Innovation it is advisable to use the concept of "skills" rather than the concept of "knowledge", since only skills make it possible to "physically" master the ability to control the factors influencing the project of a healthcare institution. Only special skills justify the participation of a subject (internal or external) in the project. Skills make it possible to control influencing factors. The analysis of subjects (actors, agents) is important because skills and concepts can arise from a variety of sources, including users, customers, suppliers and universities (Von Hippel, 2007).

For a healthcare provider the choosing of a director of a diagnostic center or medical laboratory, or a business partner, is challenging and can have a significant impact on the effectiveness of the partnership (Wood et al., 2012). Using the "stakeholder circle" tool (Walker et al., 2008), it is possible to identify partners and their possible impact (positive or negative) on the working project, as well as to distinguish four categories of partners of a healthcare institution: upstream partners (recipients of medical services provided by the health care institution); downstream partners (supply

equipment, medicines, maintain the functioning of a healthcare institution, provide additional medical services that are not provided by the healthcare institution itself); external partners (enterprises and organizations that influence the healthcare institution and provide knowledge or information for its operation); project team (all sponsors of the health care institution, as well as the management of the institution working to achieve the set goals).

However, it should be noted that categorization and judgments about subjects (actors, agents) are subjective (e.g. Grynko et al., 2018; Krupskyi & Grynko, 2018) and depend solely on the head of the healthcare institution. The role of trust in networks can be critical (e.g. Dondolo & Madinga, 2016). For example, a university can be perceived as closer than a supplier, as scientists can have more trust for the project manager helping reduce barriers to collaboration (e.g. Bruneel et al., 2010, 2016; Chukhray & Mrykhina, 2018).

2. RESULTS

Based on the generalization of Steiner et al. (2014) approach, it is proposed to distinguish four levels of subjects (actors, agents) of a healthcare institution that introduce skills to the project:

1. Level 1. All staff involved in the project of a health care institution. In our case, the project's sponsors and the project team's must be attributed to this level.

2. Level 2. All internal departments of the healthcare institution that bring their skills to the project, for example, the legal department.

3. Level 3. All external partners close to the health care institution implementing the project. "Close" means that the partner has a certain level of trust or when the subjects (actors, agents) collaborate together, for example, a current supplier or a regular customer.

4. Level 4. All other external partners of the healthcare institution who have never had a relationship with the project's owner or have a vague idea about corporate culture.

All the above-mentioned subjects (actors, agents) and their communications form the organizational structure of a healthcare institution. The boundaries of such an organizational structure include various departments of the healthcare institution and external agents, as defined by Open Innovation. Taking into account the parameters of boundaries of innovative openness of an enterprise (Steiner et al., 2012), it is possible to propose a conceptual model of the management's organizational structure for a healthcare institution in the context of promoting the implementation of Open innovation, within which four levels of externality of subjects (actors, agents) are added, taking into account the matching "factors of influence – skills" (Figure 1).

The proposed conceptual model of the organizational structure of the medical institution's management, which promotes Open Innovation, is based on a systems approach and applies matching between factors of influence and skills capital. Indeed, for the implementation of its own projects, a healthcare institution must have all the necessary skills, and if they are not mastered, then the experience of external subjects (actors, agents) can be involved. This ability to use the external potential of skills will be similar to that of Open Innovation.

To characterize the impact of organizational aspects and cooperation strategies on the ability of a healthcare institution to Open Innovation, it is necessary to carry out economic and mathematical modeling of the organizational structure of decision-making at an enterprise based on the proposed conceptual model of managing a healthcare institution. With the implementation of this conceptual model of the management's organizational structure at medical institutions (Figure 1), significant changes occur in their organizational and economic mechanism (Figure 2).

The most significant factors influencing the organization of management at a health care institution include: an increase in demand for innovative medical services and a corresponding increase in competition for the provision of such services; ineffectiveness of the existing parameters of medical institutions' funding; an increase in the cost of medical services and the cost of maintaining medical institutions; increased innovativeness of the requested medical services.
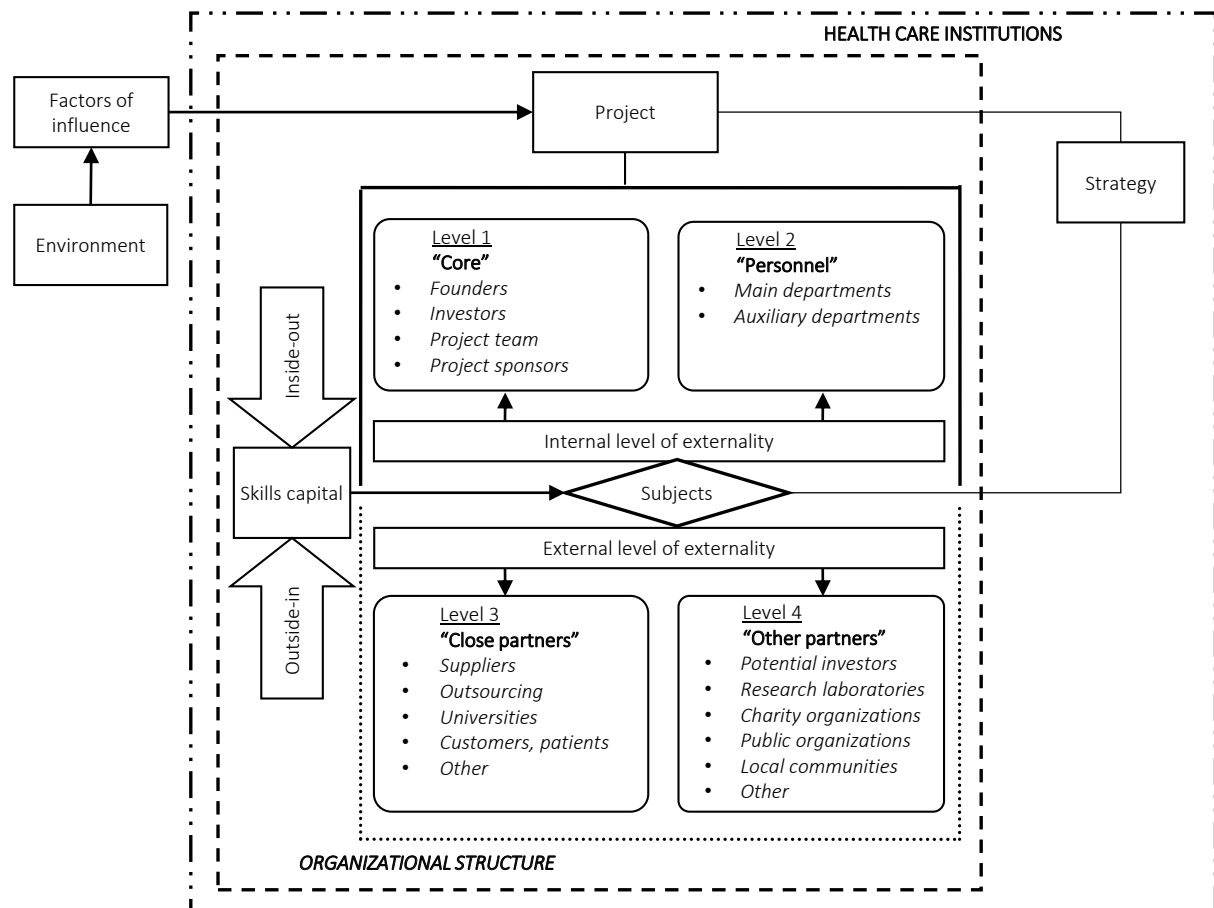
Figure 1. Conceptual model of organizational structure of a healthcare institution based on matching "factors of influence-skills" in the context of promoting Open Innovation

The same factors determine the world dominants in the formation of organizational and economic mechanism for managing health care institutions. The matching of the factors of influence on the corresponding groups of skills cause changes, as a rule, in one of the basic components of the organizational and economic mechanism. Therefore, the skills to acquire equipment and technologies, as well as crowdsourcing of medical services, compensate for the innovative lag in the content and quality of medical services, and significantly change the production and technical mechanism.

It is also influenced by the skills to improve the personnel's qualifications in other medical institutions and/or to involve specialists and equipment of independent medical centers and laboratories, which creates matching to devalue the existing qualifications of personnel. The growth in demand for innovative medical services and the corresponding increase in competition between medical institutions as a factor of influence is con-

strained by the individualization of the medical services' provision, the spread of online consultations, remote monitoring of patients' health condition, and causes changes in the organizational and technical mechanism.

A more detailed description of the proposed conceptual model of the management's organizational structure at healthcare institutions leads to the transformation of the content and structure of the healthcare institution's organizational and economic mechanism. The basis of such transformation is the identification of subject-subject interactions between elements of organizational and economic mechanisms at four levels of externality (Figure 3).

At each level of externality the components of the organizational and economic mechanism are formed, which may or may not be a part of a health care institution (represent an external or internal level of externality). At the same time, the organizational and economic mechanism expands, in-

Factor of influence – depreciation of existing staff qualifications		Factor of influence – innovative lag of content and quality

matching *matching*

Skills – professional development of personnel in other educational institutions	Skills – crowdsourcing of health services
	Skills – acquisition of technologies and equipment

Skills – involvement of specialists and equipment of independent medical centers and laboratories

Production and technical mechanism

Organizational and technical mechanism

Financial and economic mechanism

Organizational and economic mechanism

Skills – dissemination of online consultations, remote monitoring of patients' health condition	Skills – establishing a correspondence between the scope and quality of medical services and their financing
Skills – individualization of the provision of medical services	*matching*

matching

Factor of influence – growing demand for innovative medical services	Factor of influence – ineffectiveness of the existing principles of medical institutions' funding
	Skills – diversification of funding sources

matching

Factor of influence – an increase in the cost of provision of medical services and the cost of maintaining a medical institution

Figure 2. Areas of influence of the conceptual model of medical institutions' management in the context of promoting Open Innovation on its organizational and economic mechanism
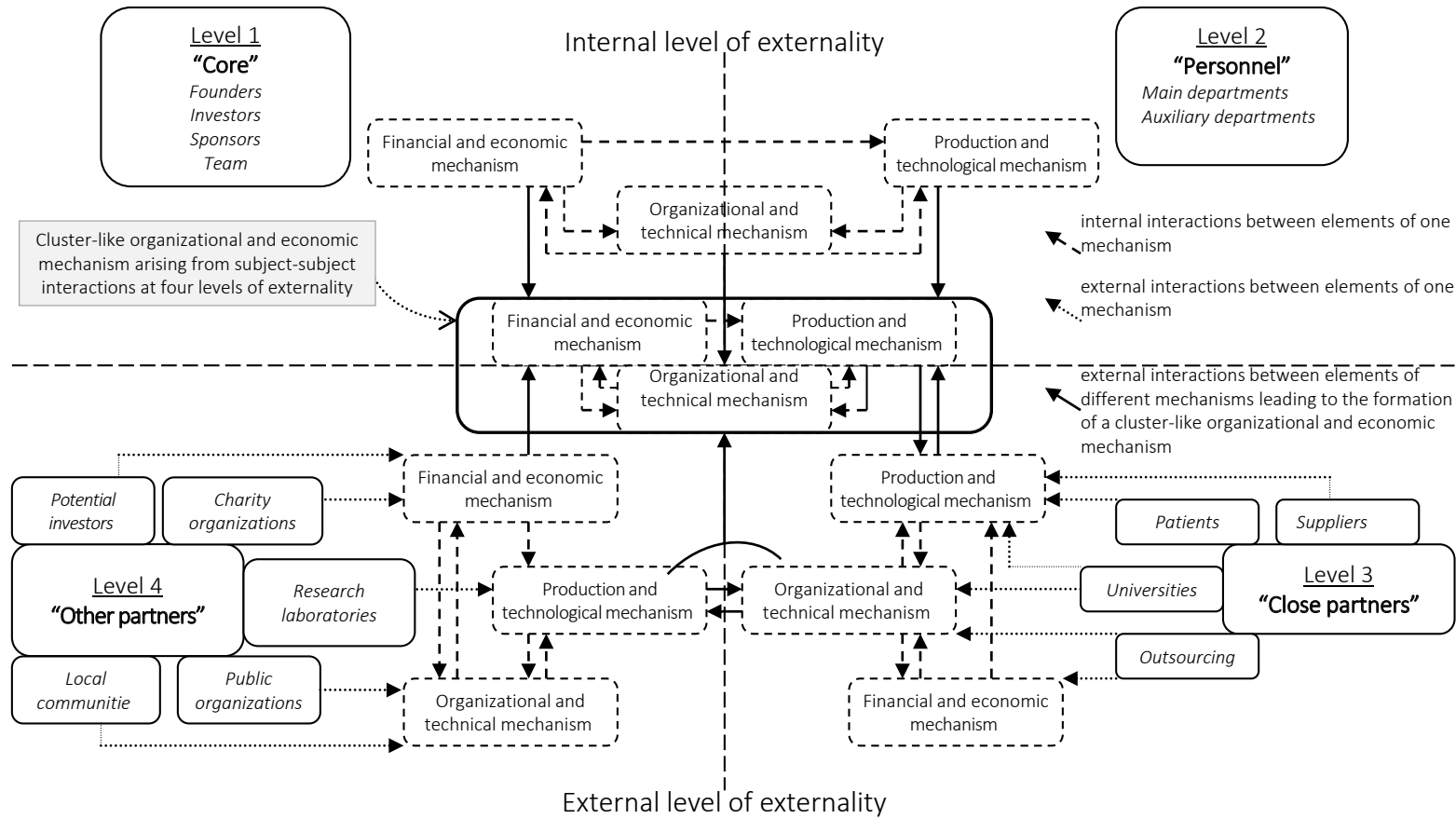
cluding both direct and reverse interactions of subjects/groups of subjects, which may or may not be a part of the medical institution's organizational structure. Therefore, if the proposed conceptual model is used, the organizational and economic mechanism is a supra-systemic formation that functions as a single whole without organizational integration of its individual components.

In ensuring a supersystem production and technological mechanism it is necessary to operate the production and technological mechanism of a healthcare institution – the first level of externality; patients receiving treatment; resource providers (material support for the treatment process),

educational institutions (staffing and advanced training) – the second level of externality.

For health care institutions it is especially important to maintain interactions regarding innovative development. Such interactions are realized within the production and technological mechanism, but they are also significant within the framework of the organizational and technical, as well as financial and economic mechanisms (Plastun et al., 2019; Kuzheliev et al., 2019). Since the innovative activity of healthcare institutions has a specific character, then in its implementation there is an interaction of subjects of all four levels of externality. Therefore, by using Open Innovation the organ-

Internal level of externality

Level 1
"Core"
Founders
Investors
Sponsors
Team

Level 2
"Personnel"
Main departments
Auxiliary departments

Financial and economic mechanism

Production and technological mechanism

Organizational and technical mechanism

Cluster-like organizational and economic mechanism arising from subject-subject interactions at four levels of externality

internal interactions between elements of one mechanism

external interactions between elements of one mechanism

Financial and economic mechanism

Production and technological mechanism

Organizational and technical mechanism

external interactions between elements of different mechanisms leading to the formation of a cluster-like organizational and economic mechanism

Potential investors

Charity organizations

Financial and economic mechanism

Production and technological mechanism

Patients

Suppliers

Level 4
"Other partners"

Research laboratories

Production and technological mechanism

Organizational and technical mechanism

Universities

Level 3
"Close partners"

Outsourcing

Local communitie

Public organizations

Organizational and technical mechanism

Financial and economic mechanism

External level of externality

Figure 3. Subject-subject interactions at four levels of externality for healthcare institutions

izational and economic mechanism of a healthcare institution significantly expands its boundaries and is transformed into an open system.

The underlying reason for the formation of such mechanism is that all subjects included in its field of action interact to obtain one result – improvement in the health of the population in general and each person in particular. The formation of each of component of the external organizational and economic mechanism is associated with a greater density of inter-subjective interactions between different levels of externality than inter-subjective interactions within the same level of externality.

Therefore, Open Innovation stimulates the interaction between health care institutions and the environment, being one of the most important components in the proposed conceptual model of medical institutions' organizational structure, leading to the expansion of the organizational and economic mechanism and the strengthening of its openness.

Simulation modeling is carried out on the basis of a conceptual model of the management's organizational structure at health care institutions that promotes Open innovation (Figure 1) and is based on the exchange of skills between subjects (actors, agents) making decisions in order to control environmental factors – matching "factors of influence-skills".

The cost/benefit approach (DeCanio et al., 2000) was chosen as the basis for simulation to recreate the functioning of a healthcare institution in the Open Innovation mode, taking into account the modifications proposed by Steiner (2014). This model can also be used to simulate the functioning of enterprises that do not practice Open Innovation.

The profitability of the subject Ω (actor, agent) a of a healthcare institution's organizational structure in the context of mastering external skills in the Open Innovation mode can be written as follows (Steiner, 2014):

$$\Omega(a) = A_a + \frac{\sum_{i=1}^{n}\left[A_i \cdot (S_{ai})\right]}{(1-A_a)} - \sum_{i=1}^{n} c_{ai}, \qquad (1)$$

where A_i – the level of mastering by the subject (actor, agent) of the relevant skills to control the

factors of influence [0,1]; n – the number of subjects (actors, agents) of the organizational structure; S_{ai} – the level of similarity between subjects (actors, agents) a and i in the context of mastering the corresponding skills [0,1]; c_{ai} – the level of costs for the transfer of skills between subjects (actors, agents) a and i [0,1].

In turn, the profitability of the subject Ω (actor, agent) a of a healthcare institution's organizational structure in the context of mastering external skills in the Closed Innovation mode is as follows (Steiner, 2014):

$$\Omega(a) = A_a + \frac{\sum_{i=1}^{n}\left[A_i \cdot (S_{ai})^{\tau_i}\right]}{(1-A_a)} - \sum_{i=1}^{n} c_{ai}^{1/\varepsilon_i}, \qquad (2)$$

where ε_i – the number of relationships between subjects (actors, agents); τ_i – the number of intermediary subjects in the context of the transfer of skills, that is, the distance between two subjects (actors, agents).

The costs of communication c_{ai}, as well as the similarity of S_{ai} subjects (actors, agents) are considered in the context of determining the effectiveness of a healthcare institution's organizational structure under the influence of the strategy of innovative cooperation.

In carrying out a simulation, a cost measurement was added in order to represent the opposite position to the acquisition of skills by the subject (actor, agent), since in the economy the exchange of information has a cost (direct or indirect). Businesses expect a return on investments and profits for the costs they incurred in relation to skills acquisition. In addition, the expansion of exchange for the acquisition of skills in accordance with Open Innovation is taken into account, because the cost of acquiring or disseminating innovations is an extremely important criterion when deciding on a policy of innovative openness of a healthcare institution.

Stages of simulation were carried out based on the Steiner (2014) approach:

1. Determination of the number of subjects (actors, agents): n.

2. Determination of the similarity matrix: S_{ab}.

3. Determination of the level of skills to control the factors of influence by the subject (actor, agent): A_a.

4. Determination of the cost matrix: C_{ab}.

5. Generation of initial population with all possible matrices of dimension п with one link.

6. Calculation of the profitability of subjects (actors, agents) and the total profitability according to equations (1) and (2).

7. Selection of matrices with the highest profitability.

8. Creation of subsidiaries $N+1$ (X times).

9. Selection of the most profitable organizational structure.

In the process of simulation, the generation of the best medical institution's organizational structure in relation to the input data and the measurement of the corresponding characteristics were carried out. Therefore, to determine all possible incidence matrices and taking into account the constraints of the computational load, a genetic algorithm was used, based on an adaptation of the approach of Camargo et al. (2013).

In the first four stages of simulation the model variables were fixed and all the parameters necessary for the algorithm execution were set. The next steps concerned the genetic algorithm itself, which is an iterative optimization process for generating an initial population (initial set of agents), as well as the measuring of efficiency and selecting the best elements to create a "child" generation. By using such operators as "mutation" and "crossing", the structures with the best characteristics are selected for inclusion in the original population, creating "child" generations, etc.

As seen in Step 9 of the simulation, a series of three mathematical metrics was used to represent different characteristics in the context of organizational performance, as defined by Durugbo et al. (2011, 2013):

1) The degree of centrality Dc_i – is the relationship between the number of subjects (actors, agents) who are in direct contact and the number of possible direct relationships in the organizational structure.

2) The degree of mediation Di_i of rank 1 is the level of access of one subject (actor, agent) through the mediation of another. The rank indicates the number of subjects (actors, agents) between the subject (actor, agent) i and the most distant subject (actor, agent).

3) The degree of centralization of powers Dp_i – is the inverse probability that the subject (actor, agent) of the institution is connected with all other subjects (actors, agents).

A number of results were obtained based on input variables and the innovative collaboration strategy. It is necessary to compare the results obtained between the organizational structure promoting Open Innovation and the organizational structure focusing on Closed Innovation in the context of testing the impact of the innovation collaboration strategy on the effectiveness of the healthcare institution's organizational structure.

To represent the choices of the innovation strategy, we fixed the importance of two levers ε_i and τ_i so that the number of links and the distance between subjects (actors, agents) had no effect on the ability to acquire external skills. For an organizational structure that promotes Open Innovation, $\varepsilon_i = 1$ and $\tau_i = 1$. The genetic algorithm made it possible to obtain more efficient organizational generations after a certain number of iterations. Ten iterations were carried out for each simulation, while twelve organizational generations were formed within the framework of the genetic algorithm. It was decided to run a genetic algorithm for $n = 8$, 10 and 12 subjects (actors, agents) in order to obtain the most reliable results and, at the same time, to check whether the number of subjects (actors, agents) plays an important role in the effectiveness of the organizational structure of a healthcare institution from the standpoint of innovative openness.

As noted, to determine the most effective organizational structures, indicators available in the

scientific literature on the analysis of social networks were used, in particular, Dc_i, Di_i, Dp_i. Such numerical criteria made it possible to compare organizational structures in the context of effectiveness and to check whether there are significant differences in the organizational structure of health care institutions depending on the innovation strategy. However, despite the possibilities that the simulation model provides with regard to taking into account the degree of heterogeneity of subjects (actors, agents), it was decided to set the values of the corresponding variables as follows: $S = 0.67$; $A = 0.67$; $c = 0.15$. For each iteration the organizational criteria for effective organizational structures of the healthcare institution (mean,

standard deviation) for the Open Innovation and Closed Innovation strategies (Tables 1-3) were summarized. The deviation (%) makes it possible to measure the difference of the structure from the standpoint of the above criteria.

To fully demonstrate changes in the organizational structure of a healthcare institution in accordance with the chosen innovation strategy, the effects of the two levers ε_i and τ_i were gradually reduced by using x. In order to fully demonstrate changes in the organizational structure of a healthcare institution in accordance with the chosen innovation strategy, the effects from two levers were gradually reduced from 0 to 1.

Table 1. Criteria for the effectiveness of organizational structure of 8 subjects (actors, agents) of healthcare institutions from the standpoint of the Open Innovation or Closed Innovation cooperation strategy

Source: Compiled and calculated by the authors.

Iteration	Open Innovation strategy			Closed Innovation strategy			Deviation (%)		
	$\bar{D}i_i$	$\bar{D}c_i$	$\bar{D}p_i$	$\bar{D}i_i$	$\bar{D}c_i$	$\bar{D}p_i$	$\Delta\bar{D}i_i$	$\Delta\bar{D}c_i$	$\Delta\bar{D}p_i$
1	5.23	0.51	0.01	2.72	0.32	0.00	92.28	59.38	–
2	5.37	0.52	0.01	4.09	0.41	0.00	31.30	26.83	–
3	5.09	0.54	0.00	3.81	0.33	0.00	33.60	63.64	–
4	4.24	0.43	0.17	6.13	0.45	0.00	−30.83	−4.44	–
5	5.80	0.46	0.34	2.72	0.32	0.00	113.24	43.75	–
6	5.37	0.52	0.17	3.14	0.29	0.00	71.02	79.31	–
7	5.52	0.51	0.00	2.72	0.29	0.00	102.94	75.86	–
8	5.37	0.43	0.17	5.72	0.50	0.00	−6.12	−14.00	–
9	3.67	0.44	0.12	5.86	0.42	0.00	−37.37	4.76	–
10	4.95	0.51	0.00	3.41	0.29	0.00	45.16	75.86	–
Mean	5.06	0.49	0.10	4.03	0.36	0.00	25.52	34.53	–
Standard deviation	0.64	0.04	0.11	1.37	0.08	0.00	92.28	59.38	–

Table 2. Criteria for the effectiveness of organizational structure of 10 subjects (actors, agents) of healthcare institutions from the standpoint of the Open Innovation or Closed Innovation cooperation strategy

Source: Compiled and calculated by the authors.

Iteration	Open Innovation strategy			Closed Innovation strategy			Deviation (%)		
	$\bar{D}i_i$	$\bar{D}c_i$	$\bar{D}p_i$	$\bar{D}i_i$	$\bar{D}c_i$	$\bar{D}p_i$	$\Delta\bar{D}i_i$	$\Delta\bar{D}c_i$	$\Delta\bar{D}p_i$
1	4.75	0.32	0.01	3.24	0.19	0.00	46.60	68.42	–
2	5.09	0.32	0.01	3.56	0.24	0.00	42.98	33.33	–
3	6.10	0.37	0.00	4.21	0.23	0.00	44.89	60.87	–
4	5.88	0.35	0.12	3.24	0.25	0.00	81.48	40.00	–
5	5.09	0.33	0.19	2.05	0.22	0.00	148.29	50.00	–
6	5.09	0.33	0.04	4.86	0.30	0.00	4.73	10.00	–
7	5.43	0.33	0.00	2.27	0.19	0.00	139.21	73.68	–
8	3.84	0.33	0.10	5.07	0.31	0.00	−24.26	6.45	–
9	7.57	0.38	0.05	4.21	0.24	0.00	79.81	58.33	–
10	5.77	0.35	0.00	5.40	0.31	0.00	6.85	12.90	–
Mean	5.46	0.34	0.05	3.81	0.25	0.00	43.30	37.49	–
Standard deviation	0.98	0.02	0.06	1.14	0.05	0.00	46.60	68.42	–

Table 3. Criteria for the effectiveness of organizational structure of 12 subjects (actors, agents) of healthcare institutions from the standpoint of the Open Innovation or Closed Innovation cooperation strategy

Iteration	Open Innovation strategy			Closed Innovation strategy			Deviation (%)		
	$\overline{Di}_i$	$\overline{Dc}_i$	$\overline{Dp}_i$	$\overline{Di}_i$	$\overline{Dc}_i$	$\overline{Dp}_i$	$\Delta\overline{Di}_i$	$\Delta\overline{Dc}_i$	$\Delta\overline{Dp}_i$
1	5.17	0.29	0.00	3.14	0.15	0.00	64.65	93.33	–
2	5.47	0.25	0.00	3.42	0.17	0.00	59.94	47.06	–
3	6.48	0.27	0.00	4.07	0.18	0.00	59.21	50.00	–
4	6.45	0.26	0.00	3.14	0.18	0.00	105.41	44.44	–
5	5.60	0.27	0.00	2.01	0.17	0.00	178.61	58.82	–
6	5.56	0.33	0.00	4.53	0.22	0.00	22.74	50.00	–
7	5.84	0.24	0.00	2.22	0.15	0.00	163.06	60.00	–
8	4.23	0.31	0.00	4.54	0.23	0.00	−6.83	34.78	–
9	7.20	0.30	0.00	4.09	0.19	0.00	76.04	57.89	–
10	6.26	0.33	0.00	4.97	0.23	0.00	25.96	43.48	–
Mean	5.83	0.29	0.00	3.61	0.19	0.00	61.50	52.63	–
Standard deviation	0.82	0.03	0.00	1.00	0.03	0.00	64.65	93.33	–

Tables 1-3 show that the strategy of innovative cooperation of a healthcare institution affects the organizational structure from the standpoint of three selected criteria Dc_i, Di_i, Dp_i. The main difference between the collaboration strategy in the context of Open Innovation and Closed Innovation is that in a closed network, skills, technologies or concepts can only be learned by internal actors, as opposed to an open network, where each actor makes its own skills available to other users.

The value of distinguishing criteria for the effectiveness of the medical institution's organizational structure varies for Di_i from 25,52% to 61,50%, and for Dc_i from 34.53% to 52.63% (Tables 1-3). Such a huge difference indicates the presence of differences in the organizational structure of a healthcare institution, depending on the chosen strategy of innovative cooperation. It should be noted that the degree of centralization of Dp_i authorities does not make it possible to draw certain conclusions due to excessive variation in values on a relatively small number of simulation experiments (Tables 1-3). Therefore, in an organization promoting Open Innovation, communications across the conventional boundaries of the health-care institution are easier and more flexible. It is within the framework of this strategy that management entities can create the necessary conditions for innovative cooperation and use the appropriate management tools.

It should be noted that there are certain limitations regarding the conceptual proposals (Figure 1) and the application of the cost/benefit approach of DeCanio et al. (2000) with the modifications proposed by Steiner (2014). But what is essential is not the building of as accurate mathematical models as possible, but a theoretical understanding of the phenomena under consideration. The main limitation is associated with the genetic algorithm (based on the adaptation of the approach of Camargo et al., 2013), with the help of which it was possible to confirm the assumption that the strategy of cooperation in the field of innovation affects organizational structure of the healthcare institution. The computational power at our disposal does not make it possible to carry out many simulation experiments on the algorithm to obtain more child organizational generations. Therefore, it is entirely possible that the results may be more accurate as the number of iterations increases.

CONCLUSION

It has been established that the strategy of cooperation, which is carried out by a health care institution, affects the organizational structure from the standpoint of three selected efficiency criteria Dc_i (degree of centralization), Di_i (degree of mediation), Dp_i (degree of centralization of powers). A strategy that is

conducive to innovative openness significantly increases the connections between the subjects (actors, agents) of the structure in the context of knowledge exchange, regardless of the distance between them and the level of similarity.

In contrast to innovative open collaboration, the Closed Innovation strategy provides that the subjects (actors, agents) will simply use their own knowledge and skills, as well as use the skills and knowledge of very close parties (although the level of such skills will be much lower), and in this case the organizational structure of a health care institution will acquire a hierarchical form.

The use of the Open Innovation strategy makes it possible to gain external knowledge and skills as part of the Outside-in process, because the interaction carried out across the boundaries of the healthcare institution is more effective. It should be noted that a large number of variables were taken into account within the framework of the simulation process, which would not have been possible in the study of a real healthcare institution. To obtain more complete results, it is necessary in further research to gradually increase the number of experiments in the process of simulation modeling of a healthcare institution's organizational structure in the context of Open Innovation.

AUTHOR CONTRIBUTIONS

Conceptualization: Tetiana Grynko, Vladyslav Shevchenko, Dariusz Pawliszczy.
Data curation: Tetiana Shevchenko, Dariusz Pawliszczy.
Formal analysis: Tetiana Shevchenko, Tetiana Grynko, Roman Pavlov.
Investigation: Roman Pavlov, Vladyslav Shevchenko, Tetiana Grynko.
Methodology: Roman Pavlov, Vladyslav Shevchenko, Tetiana Grynko.
Project administration: Tetiana Grynko, Tetiana Shevchenko, Dariusz Pawliszczy.
Supervision: Tetiana Grynko, Tetiana Shevchenko, Dariusz Pawliszczy.
Validation: Roman Pavlov, Vladyslav Shevchenko, Tetiana Shevchenko.
Visualization: Vladyslav Shevchenko, Tetiana Grynko, Dariusz Pawliszczy.
Writing – original draft: Roman Pavlov, Tetiana Grynko.
Writing – review & editing: Roman Pavlov, Tetiana Grynko, Vladyslav Shevchenko.

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