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INDUSTRIES AND INTERINDUSTRY COMPLEXES

The Role of Small Research and Service Companies as a New Subject of Innovation Ecosystems

A. A. Alekseev* (ORCID: 0000-0003-1865-8655)

St. Petersburg State University of Economics (UNECON), St. Petersburg, Russia

**e-mail: 9492154@mail.ru*

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Abstract—This paper presents the results of the research of the institutional structure of innovation ecosystems, which was completed within a grant from the European Union (#R076 CAROTS of Interreg Baltic Sea Region 2019–2021). A new actor, an institutional formation of innovation ecosystems, is highlighted and described: Small (Specialized) Scientific Service Companies (SSSC). The statistical survey, microeconomic analysis, case studies and in-depth interviews with Russian and European companies made it possible to create an SSSC business model and formulate its main building blocks, which point to the institutional specialization and unique function of an innovation ecosystem: acceleration of the technological transfer by providing scientific services (R&D, measurements, trials, analysis and testing) for startups and industry. SSSC are highly specialized scientific service micro and small private companies, founded by researchers with the goal of commercializing the founders' scientific competencies. The presence of its own lab facilities and the R&D competencies of the founders define SSSC as an mediator in the innovation process, whose scientific services accelerate the development of new products and technology by startups and the research and development carried out by the divisions of industrial enterprises. The nature and process of the self-organization of SSSC in innovation ecosystems is analyzed. The economic indicators of the pan-European segment of SSSC, the competition factors and the contractual relationships with the actors (subjects) of the ecosystems are examined: industry, startups, universities, research infrastructure. The area for future research of SSSC focused on developing the business efficiency of the actors in innovation ecosystems is set out.

Keywords: innovation, innovation ecosystems, institutions of innovation development, scientific service, MSE, RTO, innovation infrastructure

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Introduction. The concept of an "innovation ecosystem" (IE) is found (Gomes, 2018 [1]) to be the most effective model for the sustainable development of the interconnection of actors in the innovation process. Currently, an innovation ecosystem is broadly defined as (Granstranda and Holgerssonb, 2020 [2]) "... the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors."

IE self-organization (Pushpananthan, 2019 [3]) is aimed at finding effective activities and actors that accelerate innovation development. "The actors of the ecosystem try to establish the value structure and define the organizational architecture, and new actors may come on board" (Bahari et al., 2015 [4]). A popular area of academic research in the theory of innovation management is "Mapping IE" (Renando, 2020 [5]; Araujo et al., 2020 [6]; Adner and Feiler, 2017 [7]). The "Ecosystem Pie Model" mapping method (EPM) combines the created approaches. It is built on determining the interconnection of "actors with resources and activities" (Talmara et al., 2020 [8]). Unfortunately, modern research (Hannah and Eisenhardt, 2017 [9]; Jacobides et al., 2018 [10]; Kubus, 2020 [11]) has not found a united, unequivocal position in classifying the actors of IE in terms of the overall features of their economic behavior and institutional characteristics. This is in many ways explained by the high dynamics of the institutional transformation and the permanence and incompleteness of the IE self-organization process.

The highest rates of organization development of IE occurs in the R&D and scientific service sector, the mediator between startups (innovation entrepreneurs), industry and innovation infrastructure. According to various estimates, 48% of labs in Europe, whose presence is the main reason for them being included in the sector, are involved in IE (Komorowski, 2019 [12]). The variety of organizational forms and types of contractual relationships predetermines the difficulty of classifying subjects carrying out R&D and scientific services. Factors of the

evolutionary diversity of organizational forms include the variations of founders and investors (public-private), regional and sectoral peculiarities of the innovation processes, infrastructure elements and their accessibility (Ipektsidis et al., 2016 [13]). Researchers of the sector consistently analyze the balances of public-private and insourcing-outsourcing (source distribution models of internal and external knowledge) R&D services and then move on to analyzing the efficiency of the organizational options. In terms of the focus of modern scientific discussion on the organizational forms (segments) of the research and development sector, the most voiced and jointly recognized are (polarized public-private): RTOs—Research and Technology Organisations (Garrigós and Rincon 2014 [14]); CROs—Contract Research Organization (form of RTO in pharmaceuticals and medicine—Serota, 2020 [15]); Academic universities (Valavanidis and Vlachogianni, 2016 [16]]) and their affiliated structures (Roland et al., 2013 [17]); Research divisions of industry (Butler et al., 2006 [18]). In a description of European IE (Report: A Robust Innovation Ecosystem for the Future of Europe, 2020 [19]), the actors of R&D and scientific services is organizationally identified as "Universities and RTOs".

The specificity of "Universities and RTOs" as an actor is the desire to participate in symbolic, complex research projects of jointly (together with industry) creating innovation value (Oksanen et al., 2014 [20]; Ketonen-Oksi and Valkokari, 2019 [21])—small contracts and single services hold no commercial interest for them. "Successful RTOs carry out highly specialized technology tasks such as technology monitoring, development and technology diffusion in close contact with industry" (Garrigós and Rincon, 2014 [14]). In other words, "successful RTOs" are focused on contracts that allow them to exercise their broad scientific competencies and have their own research staff and labs within the framework of the full innovation cycle. At the same time, startups at the early stages of innovation projects (pre-seed, seed) need individual scientific studies, services, measurements and tests. The demand for single R&D and scientific services is significant (Audretsch et al., 2020 [22]). A market gap is occurring between the demand from researchers, innovation entrepreneurs and the focus of the Universities' and RTOs' offer. This gap has created a market niche (individual, non-complex services in the realm of scientific services) and led to the development of private micro and small (MSE) scientific service companies, whose relatively higher business efficiency (market reaction rate, price attractiveness, personal interest and responsibility of the founding researcher, productivity, etc.) has been the subject of research before (Yeaple, 1992 [23]; Tirpak et al., 2006 [24]).

The economic behavior of the MSE segment of the R&D sector is in the early stage of research (Falk and Figueira de Lemos, 2019 [25]; Ortega-Argilés and Voigt, 2009 [26]; and others). However, this corresponds to the initial stage of its institutional formation as an IE actor. The economic characteristics and business model of this actor, its positions and functions in IE are still uncertain.

Within the grant (#R076 CAROTS of Interreg Baltic Sea Region 2019–2021), aimed at researching and forming prerequisites for scaling the MSE segment of R&D and scientific services, the definition were formulated. The title of actor—"Small (Specialized) Scientific Service Companies" (SSSC) reflects the size and function, while the definition reveals the features and criteria for defining an IE actor: scientist-founded private labs carrying out highly specialized research and services.

The various research within the grant is based on the following hypothesis: within the IE architecture, "Small (Specialized) Scientific Service Companies" are formed as the actor, having a unique business model and economic characteristics.

According to the hypothesis, the objective presented was to determine the economic characteristics of the IE actor (SSSC) and build a business model with unique building blocks.

Methodology. According to the proposed hypothesis about the nature of SSSC, the object of research is determined to be micro and small (MSE) private scientific services labs established by scientists. The criteria for forming the statistical sample and selection of SSSC for the case study were formulated:

- Specialization in R&D, support, consultation, analytical research and measurement services. Classification by NACE Rev. 2 [27] refers SSSC to "M. Professional, scientific and technical activities" in codes: M71.2—Technical testing and analysis; M72—Scientific research and development; M72.1—Research and experimental development on natural sciences and engineering; M72.1.1—Research and experimental development on biotechnology; M72.1.9—Other research and experimental development on natural sciences and engineering.
- Scientist-founded private companies.
- MSE: Staff headcount < 50; Turnover ≤ €10 m or Balance sheet total ≤ €10 m).
- Own labs (fixed assets > € 0.1 m).

Research of the SSSC segment is built on the combinatorics of quantitative and qualitative methods. The quantitative approach is focused on analyzing the statistical sample, which makes it possible to mark the economic characteristics and to assess the financial indicators of the segment. The qualitative research based on surveys and case studies is aimed at identifying the nature and building blocks of the SSSC business model.

Within the quantitative analysis (Results I), which relied on data from Amadeus, a basic sampling of

4.199 companies of the pan-European (in the context of regional affiliation) SSSC segment was formed, and the financial indicators for 2019 were estimated according to the criteria given above. The sample analysis was based, firstly, on the assessment of the scale of the SSSC segment in the total volume of the market and assets of the R&D sector. Secondly, the average values for the main financial indicators that express the economic characteristics of the SSSC segment were determined. Thirdly, in order to study the dynamics of market activity and assessment of how quickly operating revenue changes, within the base sample, a selection of 232 biochemical SSSC from the pan-European segment with 10-year retrospective development was formed.

The qualitative analysis (Results II) was aimed at explaining the quantitative estimations, searching for competition factors and constructing an SSSC business model. The architecture of the building blocks for the Osterwalder business model was selected as the methodological basis (Osterwalder, 2004 [28]). The results of two waves of surveys and case studies of 14 MSE scientific services labs of the pan-European region were used as the information basis for analyzing the building blocks. The first wave of the interview is an absentee written questionnaire based on a structured questionnaire—"open" questions (blocks: general information; founding phase; functions; services; market; economy; resources; challenges and trends; case: description of fulfilled contract). The second wave is a face-to-face in-depth interview (in-person, by phone, online). The information obtained in the survey is supplemented by an analysis of the companies' financial profiles (source: Amadeus records). Accordingly, 14 cases of SSSC were created, the combined (qualitative or quantitative) analysis of which allowed the building blocks of the business model to be defined.

Results. I—Economic characteristics.

The SSSC segment is at the organizational stage in the R&D sector and in the architecture of innovation ecosystems. Its scale (from the authors' calculations for 2019) is estimated at 7.09% of the total number of employed, 4.41% of turnover and 4.1% of assets of the pan-European research and development sector. The relatively small scale of the segment can be explained by both its initial stage of institutional formation and its organizational dimensions: micro and small enterprises.

Despite its small share of the segment in the R&D sector, its economic characteristics (Table 1) point to, on the one hand, the relevance of SSSC services in IE, and on the other, to the economic attractiveness of the business (the average level of Gross Margin in the sampling is 41.18%).

In conditions of a growing demand for SSSC services among innovation entrepreneurs during the early stages of projects (pre-seed, seed) and their recognition by industry as the centers of narrow scientific services competencies, the number of companies is expected to grow in the segment with the amount in the turnover of the R&D sector remaining the same.

The scaling of companies is constrained by the specifics of SSSC with the key player of contracts being the founding scientist, who is focused, above all, on developing their own scientific research competencies and, secondly, on entrepreneurial ones. In the studied cases, (67%) of founders indicate the main problem during the formation of the company to be the low level of entrepreneurial experience and competence. The growth strategy is based on expanding the specifications of lab equipment. The company's capitalized profit serves as the main source of investment funding. To demonstrate this position, a sample of 232 biochemical SSSC from the pan-European segment, with 10-year retrospective development, was formed (using the Amadeus database).

With a relatively high weighted average sample growth rate of annual operating revenue (2010–2019) of 33%, the monotonic decrease of the indicator in retrospect can be seen (Fig. 1). One restriction or "tight spot" for scaling SSSC (in addition to the low levels of entrepreneurial skills) is the production possibilities of the contract holder, i.e., founding scientist.

The SSSC founders interviewed, on the one hand, see the potential for growing the scale of activity by attracting full-time staff, i.e., researchers, while on the other (71% of cases), they indicate the objective difficulties of headhunting and forming long-term motivation for retaining hired researchers within the possibilities of the personnel policy of the SSSC. The salary level and level of professional tasks that can be provided for the hired researchers of an RTO, as well as the scientific subdivisions of industry, are significantly higher than the financial potential of SSSC. The steady core of an SSSC (usually) is 2–3 researchers and 8–10 specialists, hired on a project basis (Table 1). Thus, the micro and small organizational format of SSSC stays the same at all development stages and does not have the potential to become larger.

An important feature of SSSC differentiating the segment from other MSE of IE actors (those involved in technological transfer, intellectual brokers and other intermediaries, as well as other service organizations at the innovation stage) is the presence of personal assets, i.e., labs and objects of intellectual property, obtained as a result of fundamental (initiated by the founder) and applied (contract) scientific research (Fig. 2). Personal labs and intellectual property objects make up a high share of the added cost in contracts for scientific services and make the business model sustainable and efficient. This efficiency is indicated by the Profit Margin level, 7.67% (average,

Table 1. Economic characteristics of SSSC (4199 companies, 2019)

Indicator	Avg	Analysis based on case study
Operating revenue, thous. €	1843.34	Most R&D contracts have a low cost of €80–900 thous., 13–200 for scientific services (measuring, testing, etc.). The average annual number of R&D contracts is 1.5, and 2–3 for services. The variation (Fig. 1) in the sample is explained by the different cost levels of the contracts (materials and components) for the areas of scientific research and testing
Number of employees	16.11	The number of full-time researchers (not including the founding scientist) is usually 2–3 and does not exceed 8 after 5 years of practice. Most workers are temporary and brought on for the period of completing a single contract. The indicated average reflects the total number of full-time and contract SSSC researchers
Total assets, thous. €	3346.58	The number of private labs (Fig. 1) is shown by the fixed assets indicator, making up half of the companies' assets. The second half consists of objects of intellectual property, created as a result of fundamental and applied R&D
Fixed assets, thous. €	1325.30	
Profit margin, %	7.67	The level of the indicators (and the sample distribution, Fig. 2) is evidence of the effectiveness of the business model
ROE, %	18.73	
Creditors, thous. €	467.10	Credit for covering overheads, salaries of full-time researchers and lab maintenance during periods of negative cashflow is given
Credit period days	70.20	
Export revenue/Operating revenue, %	33.05	Internationalization is an objective process in the R&D sector. IE is organized on the platform of scientific, innovative specialization, and not of regional affiliation (which distinguishes the concept of IE from the cluster variety)
Employee costs/Operating revenue, %	35.91	The high value of the indicator (for comparison, the average value for manufacturing is 25%) is explained by the use of full-time researchers with high scientific expertise.

distribution field in sample; Fig. 3), and the Return on Equity (ROE), 18.73%.

The presented indicator distribution fields (Fig. 2 Total assets and operating revenue; Fig. 3 Profit margin and operating revenue) in the studied sample of 4.199 companies indicates the presence of a formed SSSC core in the pan-European IE sector. The limits of the SSSC core can be stated as the following: operating revenue—€500–2.500 thous.; total assets—€100–2.300 thous.; profit margin—5–20%.

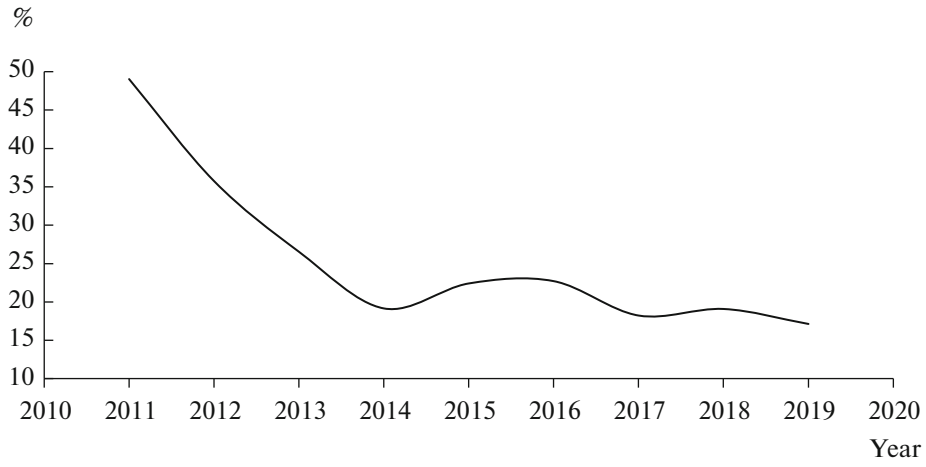

Fig. 1. Average annual growth rate of operating revenue in the sample—232 biochemical SSSC of the pan-European segment with 10-year retrospective development.

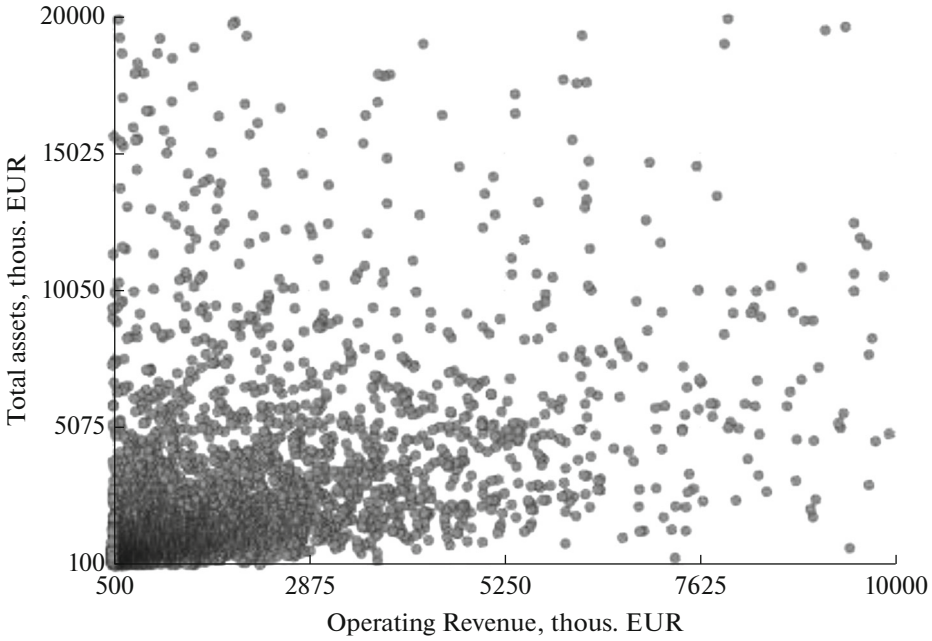

Fig. 2. Distribution field of total assets and operating revenue in sample of 4199 SSSC of pan-European IE.

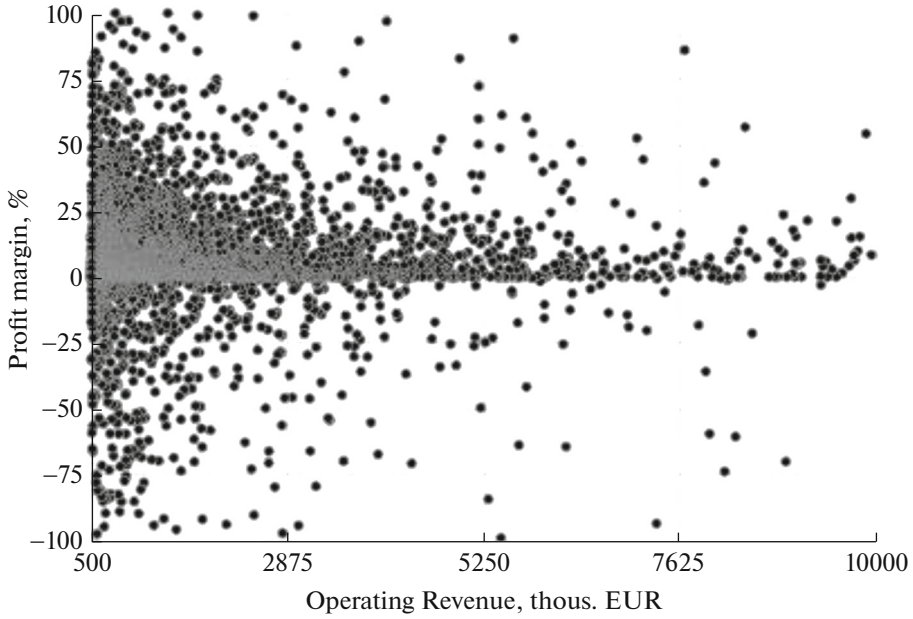

Fig. 3. Distribution field of profit margin and operating revenue in sample of 4199 SSSC of pan-European IE.

II—Business model.

The certainty of a SSSC's position in the IE architecture, its sustainability and economic efficiency are based on a unique business model (Table 2), whose building blocks are formulated based on analyzing the results of questionnaires and interviews.

SSSC's Value Proposition (Building Block, Table 2) is highly specialized R&D and services. In their relationships with customers, the following are formulated as the object of agreement: R&D; process audit; knowledge and technology effect assessment; innovative infrastructure access; prototyping; engineering services; expert services. The highly specialized services of SSSC are due to the company's founding scientist's narrow field of knowledge, expertise and areas of interest. In the case where a contract study is beyond the scientific specialization of the founder, third-party researchers are hired on a project basis. The specialization field of an SSSC is narrower than

Table 2. SSSC Business Model

Pillar	Building Block of Business Model	SSSC
Product	Value Proposition	Highly specialized R&D and services
Customer Interface	Target Customer	Researchers and industry
	Distribution Channel	Lean marketing
	Relationship	Belonging to an innovation ecosystem
Infrastructure Management	Value Configuration	Founders' scientific competencies
	Capability	Founder—executor of the contract with own lab
	Partnership	IE leaders (industry), universities, RI
Financial Aspects	Cost Structure	Staff, lab equipment
	Revenue Model	R&D and service payment

that of RTOs and universities, which combine the competencies of a significant number of full-time researchers. On the one hand, this reduces the reach of the R&D services market and, on the other, increases the competitiveness of SSSC regarding the scientific service specialization of the founder. In effect, the position of SSSC in an IE can be expressed as centers of highly specialized scientific expertise.

There are two types of SSSC strategic clients ("Target Customer"): researchers, innovation entrepreneurs (as startups) and industry. Industry uses SSSC as an outsourcing company in specialized studies, tests and measurements in situations where they do not have their own specialized labs and researchers; it requires speeding up or rechecking results of previously conducted research and conducting "independent" studies and measurements. In most studied cases of SSSC (63%), there is a landmark project with Industry, the leader of IE, in the portfolio of contract. Of course, industry signs contracts for complex research projects with RTOs; however, in cases of single, narrow "search" tasks, the scientific research competencies of SSSC are in demand. In a number of cases, innovation projects of businesses (IE leaders) were discovered in which the contracts and the objectives and stages of the process were distributed between an RTO and an SSSC. Researchers (startups) use SSSC for obtaining scientific services within the capability and potential of the lab equipment as an alternative to RTOs and universities. Marketing flexibility and productivity are key factors to the competitiveness of an SSSC.

An SSSC's "Distribution Channel" is formed on the principles of "Lean Marketing": direct marketing, networking (sci, prof, etc.), prospecting. "Sales and Marketing" makes up less than 5% of the annual expenses budget. As a rule, this is the hospitality and travel expenses of the founder. The founding scientist is directly in charge of the company's marketing and sales. They use "active marketing", which is based on monitoring the innovation activity of IE leaders ("prospecting"). Digital methods, activity in professional and social networks and participation in presentations at scientific and professional industry conferences take up a significant part of the marketing. The founder does not invest in company recognition and has no marketing plans. The founder's name is the brand of the SSSC (figuratively, not as the name of the company). Their scientific prominence guarantees the company's professionalism and efficiency in its claimed area of specialty. In other words, an SSSC's promotion, sales and market position is determined by the founder's level of fame and credibility as a scientist.

The areas of scientific and technical development of an innovation ecosystem, with SSSC as its actor, determines its leader. The "Relationship" with the "Target Customer" is based on the constant monitoring of scientific and technical strategy, innovation policy and projects of the IE leader. Accordingly, the SSSC adjusts its plan of fundamental and applied research and configuration of lab equipment. Then, using communication tools, it positions itself (founder and company) as the holder of specialized scientific expertise, allowing its to complete scientific service tasks within innovation projects of an IE.

The "Value Configuration" is based on the founder's scientific expertise. Scientists create private companies in order to commercialize their scientific expertise. The founders formed their scientific background at a university or academic research organization, where they did not have the opportunity to fulfill the commercial potential of their knowledge and skills. As a rule (87% of the sample), the founding scientists of SSSC are "graduates" of RTOs or universities where they worked.

The sustainability of the service quality ("Capability") of SSSC is determined by the fact that the contracts are directly fulfilled by the founding scientist, with their own lab facilities. All operations of the business process (from negotiations to providing the customer with the results of the analysis, research and measurements) is completed by (and/or includes the direct involvement of) the founder. This makes it pos-

sible to reach high productivity, quality sustainability and rate of scientific services.

"Partnership" is an important part of an SSSC's strategic position in creating resources for providing scientific services. An SSSC builds partnerships with IE members: universities, industrial enterprises (industry/market leaders), research infrastructure. Companies in a segment position themselves in a partnership as centers of narrow disciplinary expertise, commonly expressed as a single area of focus or problem (presented in the cases: ionic liquids as lubricants, laser focusing, enzyme development, etc.).

The "Cost Structure" is dominated (70%) by expenses for lab equipment maintenance and the salary of the full-time researchers. These expenses are constant, and the founders look for ways to cover them in conditions of unstable cash flow. Sources for this coverage include grants and state co-financing, and less commonly short-term (2–3 months, Table 1) loans. Grants and State co-financing are a significant source of compensation for an SSSC's overhead costs.

Pricing ("Revenue Model") is most often based on an assessment of the time spent by researchers. No fixed price list is offered. Of course, customer costs include (by a separate calculation) the purchase of third-party components and outsourcing services. The narrow specialization provided by the SSSC competence leader justifies the use of the cost-oriented pricing method (more commonly, cost-plus pricing) and provides a relatively high gross margin (on average 41.18%).

Conclusions and areas for further research. The academic formulation of the studied group of IE actors can be defined as scientist-founded private labs carrying out highly specialized research and services. For academic purposes, they can be designated as "Small (Specialized) Scientific Service Companies" (SSSC).

The uniqueness of the SSSC business model, determining the independent position of actors in an IE, is built on four conditions:

Scientist-founded company. Scientists create private companies in order to commercialize their scientific expertise. As a rule, the founders have a scientific background at a university or academic research organization where they were unable to find the opportunity to fulfill the commercial potential of their scientific expertise. This tendency is a new economic phenomenon and an organized alternative of spin-offs (Roland et al., 2013). This determines the "nature" of how the institutional group and IE actor (SSSC) appears.

The Value Proposition is highly specialized R&D and services (measurement, testing, modeling, analysis, expertise). SSSC hold a niche that is economically unattractive for universities and RTOs: small contracts for highly-specialized R&D or scientific services.

Capability is built on the condition that the founder-executor of the contract has their own lab. This lab opens up a wide range of possibilities for the founder: from contract R&D and services to independent participation in scientific grant programs.

In terms of Relationship, they belong to an innovation ecosystem. The development sustainability of an SSSC is determined by contractual relationships with the IE leader. This becomes possible based on the constant monitoring of innovation strategies and IE programs.

Thus, it can be seen that micro and small scientific service companies have an independent position in the R&D sector and in the architecture of innovation ecosystems. At the same time, this position is self-organizing and is not (as in other sectors) the result of targeted government programs to "support and develop SME". SSSC are formed and developed based on a "fusion" of the scientific research (initial) and entrepreneurial (acquired) competencies of the founding scientists. The presence of labs determines the independence of conducting the business process of the scientific service within the founder's specialization and the equipment profile. For this very reason, economically speaking, SSSC take on the features of an independent institutional group of the R&D sector and IE. This is highlighted by the lack of potential to scale and transform the organizational form at all stages of development.

In the scientific discussion, studies of national projections of SSSC are also found, complementing the conclusions presented by the author about the business model and economic characteristics. In the national scientific community, the question of the role of SSSC in the Russian national innovation system is at the initial stage of research; the primary vision of the segment is reflected in the works of Alekseev and Fomina [29], Klyunya at al. [30], Lavrinenko [31], Kuznetsova and Ivanov [32]. In particular, [29] proposed an estimate of the size of the Russian segment of SSSC—1155 companies (3% of the pan-European segment for 2019). Progressive growth dynamics in the national segment are also revealed: 1990–2000—220 micro and small private scientific and service companies; 2001–2010—405; 2011–2019—521. Research reveals the organizational design of SSSC as a segment of the Russian R&D sector, the role of an accelerator of innovative processes in ecosystems is formulated. In this context, the message about the need to expand (as a direction for future research) the scientific discussion about the economic characteristics and specifics of the Russian segment of SSSC is fair.

The author formulated three areas for future research, which make it possible to extend the economic vision of micro and small service organizations and to form the policy for their development.

Extension 1. Examining the SSSC segment helped to answer the question about the economic characteristics and business model within the framework of one regional plane: pan-Europe. The question about developing the SSSC segment in other regions (USA, Asia-Pacific countries and others) remains, which, in a combined analysis, would help assess the global institutional transformations of the R&D sector.

Extension 2. The SSSC segment is at the institutional formation stage. For this reason, the obtained

statistical data and cases have not yet provided an answer to a number of questions (the limits of the current research): questions about the dynamics and growth rates of the SSSC segment; evolutionary development stages of the actor in IE; economic mathematical models reflecting the drivers of SSSC's economic growth.

Extension 3. Expanding the vision by joining together SSSC into a network. SSSC companies specialize within a single scientific area. The networking and collaboration of SSSC of various IE can become a source of converging technologies (NBIC—Roco and Sims, 2002 [33]), e.g., bio-informatics and others. In other words, the network aspect of collaboration between SSSC from various IE requires further research.

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CONFLICT OF INTEREST

The author of this work declares that he has no conflicts of interest.

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