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The circular economy model and the role of solvates in regional innovative development (the case of Russian regions)

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ABSTRACT
Relevance. Recent practice has convincingly tested the fact that the transition to a circular economy is an important goal for society and individual companies, especially in resource-intensive manufacturing industries.
Research objective. The purpose of the study is to develop a theoretical and methodological basis for the creation of innovative solvates in regional industry, based on the concept of circular economy.
Data and methods. The research methodology is represented by the convergence of system-synergetic, resource-efficient and cluster approaches, which makes it possible to identify regions where integrating industrial enterprises and related fields of activity form conditions and produce values in the concept of the circular economy.
Results. The theoretical and methodological basis for the creation of new structures for the innovative development of regional industry on the platform of circularity, principles of inclusiveness, resilience and environmental friendliness has been formed; a new concept - innovative solvates has been introduced into scientific circulation. Based on the cluster analysis, the zones of localization of innovative solvates in the regions of Russia were identified. This made it possible to single out a cluster group with a high scientific and innovative potential, as well as a cluster of regions with the potential to localize innovative solvates, which included regions of industrial and resource specialization.
Conclusions. The article presents the directions of solving the problem of achieving the conditions imposed by the circular economy in the innovative solvates of the industrial sector of the region. The study is motivated by several considerations. The first is the formation of an integral conceptual and terminological apparatus, theoretical and methodological basis of research. The second is the establishment of partnerships necessary for the implementation of circularity conditions in an innovative solvate, and the analysis of ways in which a solvate can switch to a circular economy.

KEYWORDS
industrial areas of the region, innovative solvations, circular economy, resource conservation, waste-free, end-to-end digital technologies

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Инновационные сольватации субъектов региональной промышленности в условиях обеспечения циркулярной экономики (на примере регионов России)

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АННОТАЦИЯ
Актуальность. Практикой последнего времени убедительно тестируется тот факт, что переход к экономике замкнутого цикла является важной целью для общества и отдельных компаний, особенно в ресурсоемких отраслях обрабатывающей промышленности, поскольку парадигма циркулярности базируется на принципах рационального распределения и безотходного использования ресурсов.
Цель исследования. Цель исследования - разработка теоретико-методологического базиса создания инновационных сольватов (объединения инновационного типа, характеризующиеся единым замкнутым техноло-

КЛЮЧЕВЫЕ СЛОВА
промышленные сферы региона, сольватации, циркулярная экономика, ресурсосбережение, безотходность, сквозные цифровые технологии

гическим циклом) в региональной промышленности, основанных на концепции циркулярной экономики, а также инструментария определения локалитетов сольватации.
Данные и методы. Методология исследования представлена конвергенцией системно-синергетического, ресурсно-результативного и кластерного подходов, что позволяет выявить регионы, в которых интегрирующиеся предприятия промышленности и смежных сфер деятельности формируют условия и продуцируют ценности в концепте принципов и критериев экономики замкнутого цикла.
Результаты. Сформирован теоретико-методологический базис создания новых структур инновационного развития региональной промышленности на платформе циркулярности, принципов инклюзивности, резильентности и экологичности; введено в научный оборот новое понятие-инновационные сольваты. На основании проведения кластерного анализа выявлены зоны локализации инновационных сольватов в регионах России. Это позволило выделить кластерную группу с высоким научным и инновационным потенциалом, а также кластер регионов с потенциалом локализации инновационных сольватов, в который вошли регионы промышленно-ресурсной специализации.
Выводы. В статье представлены направления решения проблемы достижения условий, которые налагает циркулярная экономика в инновационных сольватах промышленного сектора региона. Исследование мотивировано несколькими соображениями. Первое - формирование целостного понятийно-терминологического аппарата, теоретико-методологического базиса исследования, а также концепции выявления локалитетов инновационных сольватаций в региональной промышленности. Второе – установление партнерских отношений, необходимых для реализации условий циркулярности в инновационном сольвате, и анализ способов, с помощью которых сольват может перейти на экономику замкнутого цикла, нацеленную на рациональное использование ресурсов всеми его участниками.

БЛАГОДАРНОСТИ
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ДЛЯ ЦИТИРОВАНИЯ
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循环经济中的区域产业参与者的创新解决方法

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摘要
现实性：最近的案例有力地证明，向循环经济过渡是社会和公司的重要目标，特别是在资源密集型的制造业。因为循环模式是基于资源合理分配和无废物利用的原则。
研究目标：在理论和方法学基础上为区域工业创造创新型联合体，这是在循环经济概念的基础上创建的。另外，文章研究了联合体的工具。
数据与方法：**研究方法以系**统协同、资源高效和集群方法的融合为代表。它可以确定在哪些地区形成了整合工业和相关企业的条件，并可在闭环经济原则和标准概念中产生价值。
研究结果：形成了在循环性平台上创建区域工业创新发展新结构的理论和方法基础。这是以循环性、包容性、韧性和环境友好性为原则的。一个新的概念被引入——创新型联合体。文章在集群分析的基础上，确定了创新型联合体在俄罗斯各地区的定位。这使得我们能够选出高科学和创新潜力的集群组，以及具有本地化创新型联合体潜力的区域集群，其中包括工业和资源专业化区域。
结论：本文提出了在实现循环经济中，地区工业部门的创新型联合体所遇到问题的解决办法。这项研究的动机有几个方面。首先是形成整体概念和术语，提出研究理论和方法基础，以及识别区域工业中创新型联合体地点的概念。其次，是建立必要的伙伴关系，以便在创新联合体中实施循环性。并分析联合体走向闭环经济的方式，**旨在使其所有参与者合理利用**资源。

关键词
地区工业领域、联合体、循环经济、资源节约、零浪费、端到端数字技术

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Introduction

New trends in the development of the Russian industry caused by the current geopolitical turbulence are aimed at intensifying innovation, digitalization, and import substitution, which are important for enhancing the national economy's resilience and competitiveness. These trends have shifted the paradigm of industrial strategic management by prioritizing rational resource consumption within the circular economy model, as opposed to the linear 'take-make-waste' approach (Batova et al., 2020; Nikitaeva, Shestopalova, 2022; Pechinina, 2021). However, the slow pace of innovation implementation in the industrial sector of the economy remains a challenge (Gorelova et al., 2021; Kleiner, 2018). Strategic plans and programs are being reoriented towards a more efficient organization of industrial development and more cost-effective use of resources. Since industry, which is one of the core elements of value chains, suffers the most from the current sanctions and external shocks, it is important to provide Russia's industrial regions with effective strategies for adapting to this new geo-economic reality.

All of the above determines the high relevance of the new area of research dealing with the innovative solutions in the regional industry, including the search for concepts, new models and mechanisms.

This study focuses on the concept of *solvates* as associations of enterprises that can spur innovation. This term is borrowed from chemistry and in the context of this article it is understood as an association of companies interacting throughout the entire closed technological cycle (Matveeva, 2021). In other words, a solvate is a cluster of a special kind aimed at the joint development and use of innovations in a cyclical environment, for example, a cluster comprising participants of a closed technological chain. The cores of such clusters can be the drivers of innovative growth in a regional industry. The cores establish symbiotic relationships with enterprises of their own sphere and related fields within the framework of a single value-added chain.

Large units of the regional industry act as top of the solvate, which is associated with their leading role in the industrial development of the region. They contribute to the development or maintenance of progressive dynamics, since they often form basic links connecting the leading and lagging functional zones of the industrial complex (Matveeva, 2020; Nikitaeva et al., 2021; Kuizheva et al., 2021).

From the above-described perspective, the basis of innovation is the circular economy model, in which consumption and production occur in closed loops and meet the three key conditions: resources are used to the maximum, waste is not accumulated, and there is no negative impact on nature (Baldassarre et al., 2019; Bacovis, Borchardt, 2021; Gomonov et al., 2021; Ming-Lang T. et al., 2021; Razminiene, 2019; Wang et al., 2021). The current economic system is complex and involves numerous participants with different economic interests, resulting in an unbalanced system. This imbalance does not allow for the formation of a material basis to achieve a synergistic and multiplicative effect. The idea underlying integrated resource potential management is not only to function according to an innovative model but also to promote connections and relationships among the participants based on innovation. To achieve this, a closed solvate model with a single goal is insufficient. Instead, the focus should be on achieving rational symbiosis among the participants and promoting innovative resonance and response across all solvate subsystems. By doing so, the system can be optimized to achieve the desired outcomes.

The theoretical significance of this paper lies in the introduction of the new category of solvates as an interdisciplinary phenomenon, combining the approaches of the theory of industrial development, the concept of industrial production modernization, management of the resource potential of a regional industry, import substitution, circular economy and cluster approach. The findings presented in this paper may be of interest to the management of industrial associations and regional authorities and policy-makers. The article also presents avenues for further research aimed at finding solutions to the problems of regional industrial development.

The purpose of the study is to develop a theoretical framework around the concept of solvates and circular economy and propose methodological tools for the investigation of innovation processes in regional economies. This aim determines the following research objectives:

- By applying the ecosystem approach, develop the concept of solvates and describe its role in the industry of a region based on the principles of inclusiveness and resilience;

• Consider the potential of the circular economy concept as a business model underlying the use of solvates;

• Describe the procedure for identifying regional localities for the creation of solvates;

• Identify the optimal localities for the creation of solvates.

Theoretical framework

In today's world, the processes of globalization, together with the negative impact of the sanctions, exacerbate the problem of regional fragmentation in Russia. In the structure of the regional economy, the problem of asymmetry of innovative development in industrial subsystems is looming large. Therefore, it is necessary to adopt a differentiated approach in devising innovation mechanisms and creation of industrial alliances, involving actors from other spheres, to build a single chain of new value creation. These mechanisms should be flexible and should be adjusted to the new needs of the state, to regions' industrial specialization and potential. In this regard, the above-described concept of solvates and the synergistic effects they produce gain relevance.

The principle of inclusiveness underlying the idea of solvate means equal rights for all its participants and the use of their potential, in particular creative potential. In the inclusive economy, each participant can be effectively involved in the technological process. The concept of inclusive economy plays a major role in the solvate theory as it explains the "rules of the game": within a solvate, participants are given unhindered "access" to resources (people, information , technologies, finance, etc) and they can also exchange them; participants take part in goal-setting and strategy-building, participants retain their economic independence but they need to abide by the norms of social responsibility.

As we said above, the term 'solvate' was initially used in the context of physical and chemical studies, more specifically, it was used as part of the chemical theory of solutions (or solvation theory) developed by Soviet physico-chemist Ivan Kablukov (Kablukov, 1935). This theory was taken further by A.M.Azzam (Azzam, 1954, 1960), O.Y.Samoylov (Samoylov, 1957, 1972) and A.S.Kazak.

The term 'solvate' was adapted to the business and economic context, in particular the concept of circular economy, by L.G. Matveeva in "Digital Meridians of the Adaptive Business Paradigm of Innovative Solvation in an Industrial Ecosystem" (Matveeva, 2021). Solvate is a separate production subsystem oriented specifically towards innovative development in compliance with the fundamental principles of the circular economy, e.g. the rational distribution of resources among the participants and maximum resource use; non-waste production (reasonable resource consumption and resource efficiency); "greening" of manufacturing, that is, organization of production processes based on the concept of closed cycles of substances in the biosphere ("green economy").

The ways of using resources by participants of the industrial ecosystem are constantly changing due to the transformation of vertical and horizontal value chains laid down in the strategic documents of the Russian Federation.[1] In other words, the ongoing technological revolution brings about significant transformations in the industry, including the formation of alliances between different economic entities (Kiseleva, Nikitaeva, 2021; Kuizheva et al., 2021). Such alliances may provide a foundation for the development of ecosystems of a special kind, "open systems of dynamic interaction" (Doroshenko, Shelomentsev, 2017). These ecosystems participate in internationalization processes and help enhance national export potential (Ayakwah, 2021).

The advantage of the ecosystem approach in relation to solvates in industry is that it allows us to tackle the problem of balancing participants' interests, contributing to the rational use of resources. Some studies emphasize that "healthy" industrial ecosystems where rational resource use is possible are important for the innovative development of a region (Gorelova et al., 2021; Koroleva, 2021; Kosolapova et al., 2022). The diagnostic results that identify the factors necessary for achieving rational symbiosis in industrial alliances demonstrate that the process of developing industrial innovations can lead to the creation of innovative impulses in the external environment (Doroshenko, Shelomentsev, 2017; Kleiner, 2018).

The circular business paradigm that underlies solvates' operation is aimed at three main goals. Firstly, it seeks to harmonize the resource supply of all participants in the solvate system. Secondly, it aims to restore the original cost of products at the end of their use, in order to ensure eco-

[1] Presidential Decree of 21 July 2020 N 474 "On the national goals of the development of the Russian Federation until 2030".

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nomic efficiency, particularly in terms of industrial innovations. And thirdly, it seeks to reduce the negative impact on the environment through restoration operations and by restoring the initial cost of the products. These goals are focused on meeting the social, economic, and environmental requirements of sustainable development in the industrial and economic system of the region.

The idea of a circular economy is widely discussed in research literature, in particular there is a growing body of research on industrial ecosystem management in a circular economy. For large manufacturing companies, a two-stage transformation model is used. The transition to a circular economy is an important goal for many companies, especially in resource-intensive manufacturing industries. However, "the complexity of the structure and the interdependence of the participants in the solvates means that none of them can achieve the goal alone and a system-wide "conducting" is needed. Therefore, the transition to a circular economy is possible in two stages: assessing the readiness of the ecosystem and transforming the ecosystem. At each stage, specific and additional mechanisms are activated" (Parida, Burström, Visnjic, Wincent, 2019). In Russian studies, the theoretical foundations of the circular economy, its basic principles, the specifics of their implementation in different countries, as well as the process of transformation planning and management are investigated (see, for example: Batova, 2020; Pechinina, 2021; Kosolapova et al., 2022; Nikitaeva, Shestopalova, 2022). In addition, the following models are considered, including models based on value chains ; product life cycle extension; sharing economy; product as a service (servicization); recovery and recycling.

Despite a noticeable increase in scholarly interest in the circular economy in industrial associations of various types (including clusters), a number of methodological "gaps" are found. In this paper, we intend to focus on the role of the circular economy in the management of industrial solvates and discuss the prospects of this model's practical application. The main goal of the strategic development of solvates in regional economies should meet the following requirements:

• increasing the level of national security due to the implementation of innovative projects of economic and social significance within the solvates. Such projects should be aimed both at solving the problems of resource conservation and resource efficiency as well as a wide range of social issues;

• increasing the competitiveness of domestic industrial production in world markets through the implementation of an import substitution policy;

• improving the quality of life through the production of import-substituting products within the solvate framework. The latter implies that industrial associations should have stimulating and motivating mechanisms for improving the quality of the workforce.

Conceptually, this study relies on the notion of solvates, more specifically, innovative industrial solvates, and their role in innovative development in line with the above-described principles of the circular economy. It would, therefore, make sense to introduce another related term – *solvation* – to describe the interactions of solvate participants centred around the core (driver) of industrial innovative development. These actors may belong to different economic sectors, which means that here we are talking primarily about intersectoral interactions, which may differ depending on the degree of (in)dependence of the solvate's participants and in the nature of their relationships with each other. Based on the degree of this dependence, we can distinguish constant, primary and secondary solvations. The degree of dependence is determined based on the number and ratio of phases around a central molecule or a larger particle – the core of an industrial innovative solvate. In other words, solvations contain permanent, primary and secondary solvate shells formed around the nucleus:

• permanent solvation is formed by those participants who have strong ties with the core and are in continuous relationship with it (for example, providing the production process);

• primary solvation consists of 4 to 12 participants, who, forming the solvation field, are directly connected with its core and have a single vector of strategic development;

• secondary solvation is based on the interactions of the nucleus with economic agents that are not part of the primary solvation but influence the ordering of connections in its field.

The number of participants that belong to the immediate environment of the solvate's core (participants in permanent and primary solvation) is called the coordination (solvation) number.

Figure 1 schematically shows a model of solvate formation.

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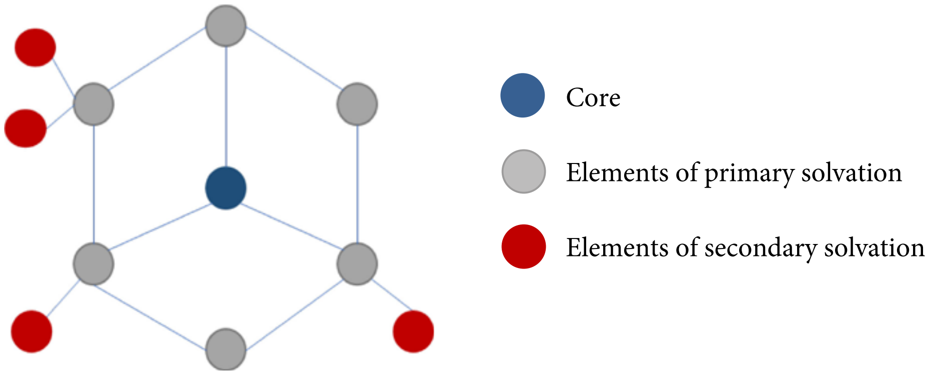

Figure 1. *Schematic representation of an innovative industrial solvate*
Source: Compiled by the authors

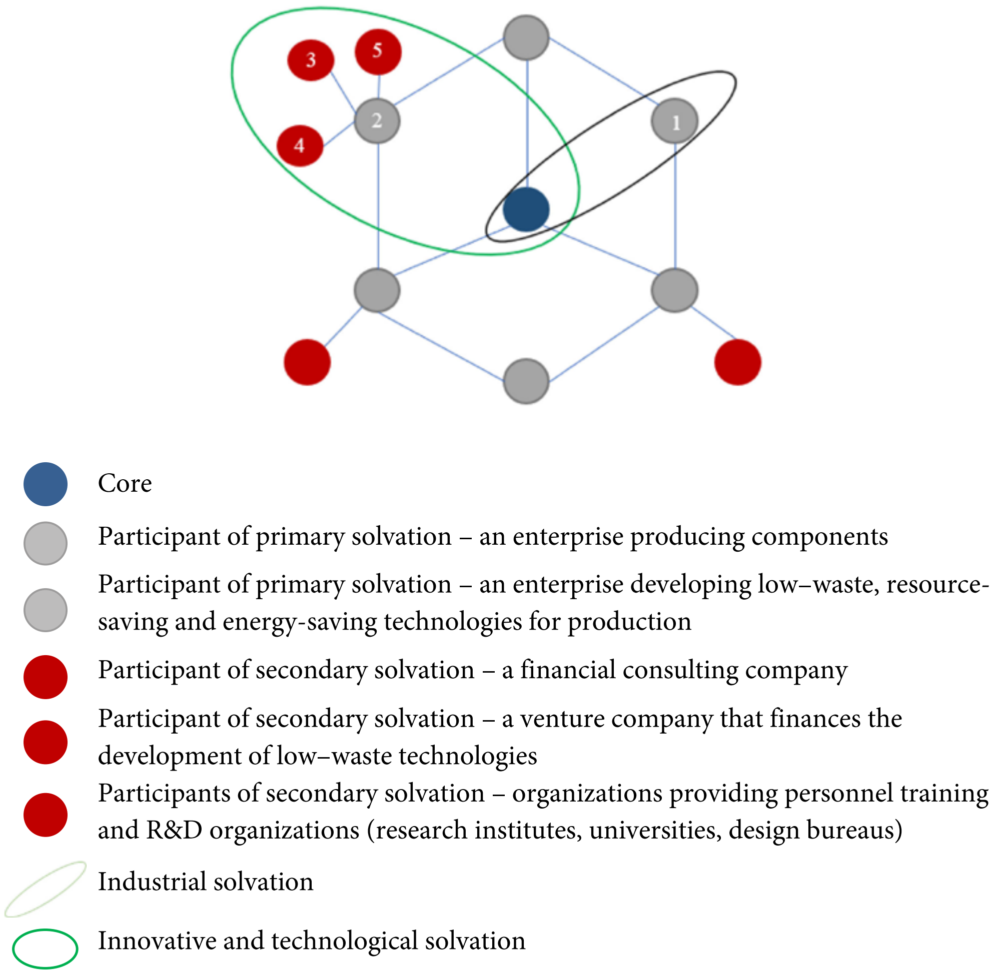

Figure 2. *Typology of solvation participants and their*
Source: Compiled by the authors

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The efficiency of innovative solvations in industry depends not only on the rational resource allocation among all participants in the solvate system, but also on the nature of their long-term interactions. Managers can improve their planning and execution by understanding the elements of an innovative solvate and the relationships between them. This creates a multilevel system for managing the process of rational resource use in innovative industrial solvates. As solvation moves from one level to another, it creates new synergies that are directed by the corresponding level's control actions. In other words, each level of the solvation system contributes to the overall synergistic properties of the system as a whole, with control actions at each level driving the process. Developing an appropriate methodology for the study of solvates requires integrating various approaches, such as structural-functional, regulatory, system-synergetic, subject-object, and level, to form a conceptual and instrumental base for the formation of a multilevel system of structural and functional management of solvates' resource potential.

Given the current scientific and practical interest in exploring the potential of circular economies, particularly within the smart solvate industry, it is necessary to consider the various options for their structure. This will help managers make better decisions by taking into account the internal and external factors and conditions of innovative solvates. One of the management goals is to determine the spatial distribution of solvates from these methodological and conceptual perspectives.

Method and Data

In modern economics, there is an impressive set of tools for assessment of various parameters of regional systems, especially those that are characterized by nonlinearity and high volatility. Indicative methods are widely used for to identify local points of growth in regional industries. They can be adapted to the purpose of this study (the choice of indicators) to devise integral indicators that characterize various parameters of a regional economy.

Another tool is the rating method based on calculating and assigning scores to regions within a given parameter (e.g. potential for creating innovative solvates).

The third type of tools is building forecasting models. This method is particularly suitable for identifying the optimal localities for innovative industrial solvates and the key factors influencing such decisions. In this context, of methodological interest is the study on the adaptation of entropy and gray forecasting methods to assess the relationship and forecast financial development, technological innovation and economic growth in China (Wang, Tan, 2021). By applying the methods described in this study, it is possible to determine trends for the period of 2019-2024, identify the degree of connection between the parameters and their differentiation between regions, and also to draw a conclusion about the strengthening / weakening of the links between the given parameters in this period.

Diagnostics and forecasting of the future state of individual regional subsystems can be conducted by using artificial neural networks (Losev, Tolkacheva, 2021). The procedure for using neural networks involves the collection of retrospective data, the formation of a database and regression analysis in order to build predictive dynamics. A possible disadvantage of this model is that it requires a lot of effort and time on the part of the research to process a large amount of data for each of the indicators.

A promising approach to identifying regional solvation localities is through cognitive modeling, which can predict the effects of implementing point solutions for the innovative development of industrial ecosystems. In a recent publication by Gorelova, Matveeva, and Chernova (2021), they developed management decision support models to form the elements of an innovation ecosystem and evaluate the relationships between them. The models can also assess the degree of management influence on these elements in alignment with the goals of medium and long-term development.

The possibilities of mathematical modeling are constantly expanding and supported by real applied tools. Within the framework of this study, we are going to use cluster analysis in order to identify regional localities for innovative industrial solvates. Cluster analysis has repeatedly proven its effectiveness for solving problems of a similar scale. One example is the use of cluster analysis to solve the problem of improving the security of the information system of a regional innovation cluster, in which the available resources must be fully used and performance must be controlled (Kirilchuk et al., 2022). The undoubted advantage of cluster analysis is the ability to break down the totality of an object both by one parameter and by a number of features, as well as the ability to take into account a variety of initial data (parameters) characterizing the localization of innovative solvates in the region.

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Our research procedure was as follows:

Stage 1. Determination of the range of indicators characterizing the localization of innovative solvates in a given region. This is done by assessing the influence of factor indicators on the resulting indicator. The indicator "Volume of innovative goods, works, services" was chosen as the resulting indicator to identify the localization of innovative solvates.

The factor indicators are as follows: "Number of patent applications filed"; "Investments in fixed assets", "Number of personnel engaged in scientific research and development", "Costs of production and sale of products (goods, works, services) (expenses for energy and water)".

Stage 2. Collection and processing of statistical data in order to identify innovative solvates in industry.

Our study relies on the official data from the portal of the Federal State Statistics Service[2], the Unified Interdepartmental Information and Statistical System (EMISS)[3]. Processing of time series and formation of the database was carried out by using Microsoft Excel. We created a database for Russian regions, which includes the following indicators:

1) Scope of innovation - the volume of innovative goods, works, services (million rubles) 2019.

2) Patent application - the number of patent applications filed (pcs) 2019.

3) Investment - investments in fixed assets (million rubles) 2019.

4) Staff - the number of R&D personnel (people) 2019.

5) GRP - GRP per capita in 2019 (RUB).

6) Water costs - costs of production and sale of products (goods, works, services) (water resources costs) (thousand roubles) 2019.

7) Energy costs - costs of production and sale of products (goods, works, services) (energy costs) (thousand roubles) 2019.

Some of the indicators described above are not available in official sources due to the requirement of confidentiality of primary statistical data received from organizations, in accordance with Federal Law No. 282-FZ of 29.11.07 "On Official Statistical Accounting and the system of State Statistics in the Russian Federation" (paragraph 5, Article 4; paragraph 1, Article 9). Therefore, these data were excluded from our analysis: the data on the Jewish Autonomous Region, Chukotka Autonomous District, Altai Republic, and the Republic of Ingushetia.

Stage 3. Correlation analysis to identify the territorial and sectoral localities of innovative solvates.

Stage 4. Cluster analysis. Data normalization was performed prior to analysis. Clustering is carried out by the K-means method in two stages. The first iteration is aimed at identifying driver regions. Repeated analysis was carried out for cluster 3 to identify regional localizations of innovative solvates. The "Silhouette" coefficient was used to determine the number of clusters in two stages of clustering. The calculations were carried out in the Python software package (Jupiter Notebook environment).

Results

The collected and processed data were used for correlation analysis, which was carried out in order to identify the locations of innovative solvates in Russian regions by showing the relationship between factorial and resultant indicators. The variables are quantitative and continuous, which made it possible to use correlation analysis to find the relationship between them.

Their results are presented in Table 1 in the form of a correlation matrix, indicating the significance of the p-value coefficients.

[2] Federal State Statistics Service. Available at: https://rosstat.gov.ru. (data 14.05.2022)

[3] Unified interdepartmental information and statistical system EMISS [Available at: https://fedstat.ru . (data 14.05.2022)

Table 1

Correlation matrix[4]

	Scope of innovation	Patent applications	Investment	Staff	GRP	Water costs	Energy costs
Scope of innovation	1.0***	0.78***	0.71***	0.73***	0.36**	0.88***	0.58***
Patent applications	0.78***	1.0***	0.79***	0.97***	0.3**	0.65***	0.27*
Investment	0.71***	0.79***	1.0***	0.82***	0.6***	0.66***	0.63***
Staff	0.73***	0.97***	0.82***	1.0***	0.32**	0.59***	0.24*
GRP	0.36**	0.3**	0.6***	0.32**	1.0***	0.42***	0.52***
Water costs	0.88***	0.65***	0.66***	0.59***	0.42***	1.0***	0.74***
Energy costs	0.58***	0.27*	0.63***	0.24*	0.52***	0.74***	1.0***

Source: Compiled by the authors

[4] significance of coefficient * -p-value 0.05; **- p-value 0.01; ***- p-value 0.001

According to the results of the analysis, the indicator "Volume of innovative goods, works and services" demonstrates a strong correlation with such indicators as "Number of patent applications filed", "Investments in fixed assets", and "Production and sales costs" (the latter includes water and energy costs).

The relationship between GRP as a general indicator of regional economic development and other variables can be described as moderate, which may be due to the binding of these indicators and GRP to the same time period. This situation, which obviously does not correspond to reality, can be addressed by including a wider range of indicators, including "Volume of innovative technologies introduced" of previous periods, since the impact of this indicator on GRP has a prolonged effect.

It is worth noting that there is a strong correlation between the "Volume of innovative goods, works, and services" and the "Costs of water and energy resources" indicators. This indicates a wider application of resource-saving technologies, which, in the initial stages (2019), involved significant costs for the implementation of innovative water and energy-saving technologies. This fact is supported by practical evidence and is in line with the principle of "reasonable" resource consumption within the circular economy paradigm.

Due to the fact that the we obtained a voluminous array of data that requires appropriate processing and systematization, cluster analysis was carried out. As a result, we built clusters depending on regions' performance in the indicator "Volume of innovative goods, works, services". We identified the localization zones of innovative industrial solvates by the K-means method according to the selected indicators. The results of all stages of cluster analysis are shown in Figure 3.

Based on the first stage of cluster analysis, two distinct clusters can be identified, each with its specific characteristics. The first cluster is made up of regions with a high scientific and innovative potential, and the maximum values of all indicators except for energy costs. This may be due to the absence of energy-intensive enterprises in these regions. The first cluster is also characterized by the concentration of research organizations and analytical centers that develop and test innovative technologies. In contrast, the second and third clusters have lower values across all indicators, with the third cluster being the least developed.

Figure 3. *Results of the first stage of cluster analysis of Russian regions*
Source: Compiled by the authors in https://www.mapchart.net/russia.html

The second cluster includes regions with pronounced industrial and resource specialization (metallurgy, mechanical engineering and fuel energy, mining (oil, gas, etc.)). The prevalence of these industries in regional economies explains the high level of energy costs. Figure 4 shows a graph of cluster averages.

The third cluster is the largest and comprises the regions whose industrial specialization is not as pronounced as in the second cluster. In order to identify the features of territorial and industry localities in this cluster, the second stage of clustering was carried out by using the data on the regions included in this cluster.

The results of the second stage of cluster analysis and the use of information obtained as a result of the first stage of clustering are shown in Table 2.

A more detailed analysis shows that the regions of the first cluster of this clustering stage (3_1) have a mixed-type economy represented by developed manufacturing industries (mechanical engineering, shipbuilding and ship repair), construction, energy, trade, food production, and agriculture. In addition, these regions have a lot of research organizations and universities engaged in R&D. Despite the sufficiently high volumes of innovative goods for regions of this type, their GRP is rather small.

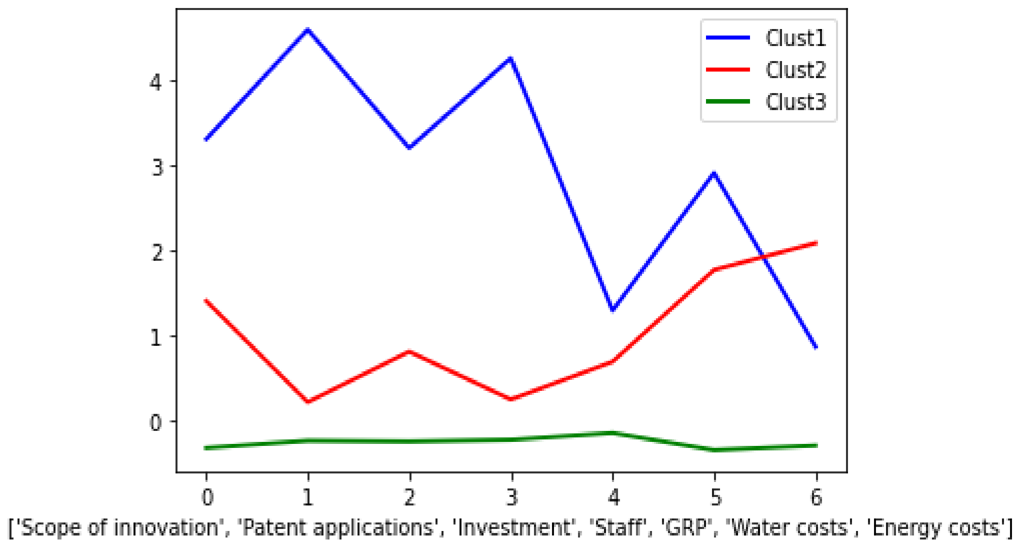

Figure 4. *Graph of averages for each cluster*
Source: Compiled by the authors

Table 2

Results of the second stage of cluster analysis of the regions in the third cluster after the first stage

Cluster 3_1- 5 regions
Voronezh Region, Krasnodar Region, Rostov Region, Perm Region, Novosibirsk Region
Cluster 3_2 -25 regions
Belgorod Region, Vladimir Region, Kaluga Region, Lipetsk Region, Tula Region, Yaroslavl Region, Komi Republic, Arkhangelsk Region, Vologda Region, Leningrad Region, Murmansk Region, Volgograd Region, Stavropol Region, Udmurt Republic, Orenburg Region, Saratov Region, Ulyanovsk Region, Irkutsk Region, Kemerovo Region, Omsk Region, Tomsk Region, Republic of Sakha (Yakutia), Primorsky Region, Khabarovsk Region, Sakhalin Region
Cluster 3_3- 37 regions
Bryansk Region, Vladimir Region, Ivanovo Region, Kostroma Region, Kursk Region, Oryol Region, Ryazan Region, Smolensk Region, Tambov Region, Tver Region, Republic of Karelia, Kaliningrad Region, Novgorod Region, Pskov Region, Republic of Adygea, Republic of Kalmykia, Republic of Crimea , Astrakhan region, Sevastopol, Republic of Dagestan, Kabardino-Balkar Republic, Karachay-Cherkess Republic, Republic of North Ossetia - Alania, Chechen Republic, Republic of Mari El, Republic of Mordovia, Chuvash Republic, Kirov region, Penza region, Kurgan region, Republic of Tyva, Republic of Khakassia, Altai Territory, Republic of Buryatia, Trans-Baikal Territory, Kamchatka Territory, Amur Region, Magadan Region

Source: Compiled by the authors

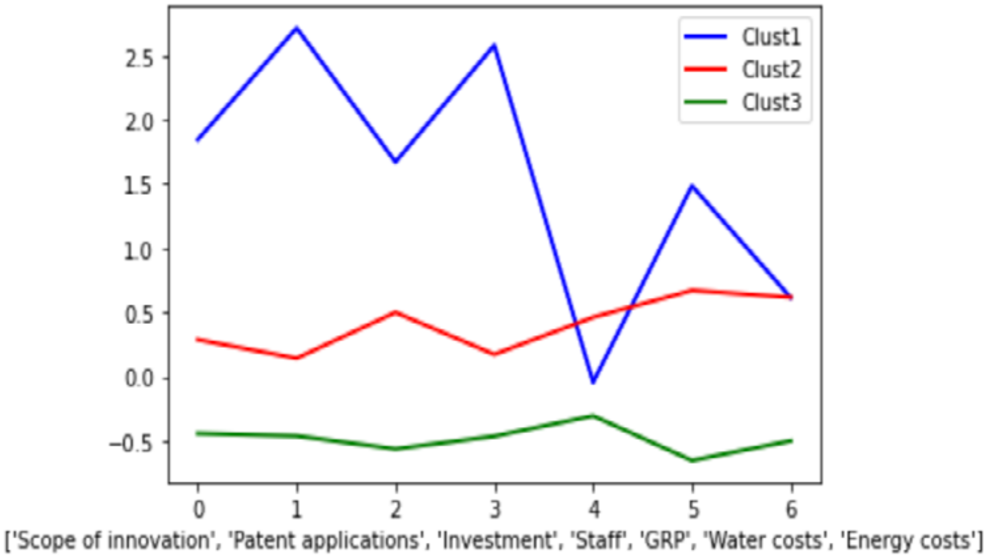

Figure 5. *Graph of averages for each cluster*
Source: Compiled by the authors

Figure 5 shows the average graph for each cluster that resulted from the second stage of clustering regions. Specifically, these regions were those that were initially placed into the third cluster during the first stage of clustering.

The economy of the regions in the second cluster at this clustering stage (2/3) has a variety of industries such as mechanical engineering, power engineering, aluminum production, and forestry. The water and energy costs of the regions in the second and first clusters are almost the same, and the level of GRP is the highest. According to the results of the second stage of clustering (3/3), the third cluster includes regions with a low level of economic development, because they lack large industrial enterprises, suffer from unemployment and their economies are dominated by small agricultural production.

Conclusion

The study of solvates in relation to the Russian regional industrial context reveals zones of innovative industrial growth where their use can have a maximum effect. Solvates consist of a core (driver) and the inner and outer "shell" of enterprises serving it in a closed value chain.

In the future, it will be increasingly important to study innovative solvations in the regions of the clusters obtained in the first stage of cluster analysis. It is also necessary to investigate the solvates identified in the regions of the first cluster obtained in the second stage of cluster analysis, taking into account the general characteristics inherent in the identified cluster groups.

This study has identified regions with a significant scientific potential created by universities, research organizations, experimental design bureaus and other organizations producing innovations. There is also a group of regions with a high production potential, characterized by industrial and resource specialization and developed manufacturing industry. They form "innovation funnels" on the map of Russia or what can be described as industrial innovative solvates.

A possible avenue for further research could be the study of solvates both in the regions of clusters identified at the first stage of cluster analysis, and in the regions of the first cluster identified at the second stage of cluster analysis. At the same time, it is necessary to take into account the general characteristics inherent in the identified cluster groups.

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