Economics of agricultural sectors

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Methodology of research infrastructures local based industrial analysis (case of agriculture)

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Abstract. *The article examines the role of research infrastructures in the*

formation of effective mechanisms for locally oriented technology transfer in agriculture. Particular attention is paid to the analysis of research infrastructures as key elements of the innovation system that ensure the generation of knowledge, conducting applied research, testing technological solutions and their adaptation to regional economic conditions. The aim of the article is to develop a methodology for analyzing research infrastructures in the system of locally oriented technology transfer and determine their role in supporting the innovative development of the agricultural sector. The paper analyzes modern approaches to understanding research infrastructures and substantiates their expanded interpretation as a multi-component institutional and organizational system that combines material and technological resources, institutional management mechanisms, network interaction of participants in the innovation process, technology transfer tools and locally oriented mechanisms for implementing innovations. The study identifies key components of research infrastructures, including material and technological, institutional, network, transfer-innovation and locally oriented, and also defines their functional role in ensuring the full innovation cycle. It is shown that the effective functioning of research infrastructures contributes to the strengthening of interaction between scientific institutions, agrarian business, authorities and local communities, which ensures a more effective adaptation of innovations to the needs of agricultural production. It is proven that the integration of research infrastructures with technology transfer mechanisms and the smart specialization approach creates the prerequisites for the formation of local innovation ecosystems, increasing the productivity of the agricultural sector, spreading sustainable technological practices and strengthening the competitiveness of the regional economy.

***Keywords**: research infrastructures, technology transfer, agricultural sector, innovation ecosystems, smart specialization, sustainable agriculture.*

Методологія локально орієнтованого галузевого аналізу дослідницьких інфраструктур (на прикладі аграрного сектору)

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Анотація. *У статті досліджено роль дослідницьких інфраструктур у формуванні ефективних механізмів локально орієнтованого трансферу технологій у сільському господарстві. Особлива увага приділяється аналізу дослідницьких інфраструктур як ключових елементів інноваційної системи, що забезпечують генерацію знань, проведення прикладних досліджень, тестування технологічних рішень та їх адаптацію до регіональних умов господарювання. Метою статті є розроблення методології аналізу*

дослідницьких інфраструктур у системі локально орієнтованого трансферу технологій та визначення їх ролі у підтримці інноваційного розвитку аграрного сектору. У роботі здійснено аналіз сучасних підходів до розуміння дослідницьких інфраструктур та обґрунтовано їх розширене трактування як багатокомпонентної інституційно-організаційної системи, що поєднує матеріально-технологічні ресурси, інституційні механізми управління, мережеву взаємодію учасників інноваційного процесу, інструменти трансферу технологій та локально орієнтовані механізми впровадження інновацій. У межах дослідження виокремлено ключові компоненти дослідницьких інфраструктур, зокрема матеріально-технологічний, інституційний, мережевий, трансферно-інноваційний та локально орієнтований, а також визначено їх функціональну роль у забезпеченні повного інноваційного циклу. Показано, що ефективне функціонування дослідницьких інфраструктур сприяє посиленню взаємодії між науковими установами, аграрним бізнесом, органами влади та місцевими громадами, що забезпечує більш ефективну адаптацію інновацій до потреб аграрного виробництва. Доведено, що інтеграція дослідницьких інфраструктур із механізмами трансферу технологій та підходом смарт-спеціалізації створює передумови для формування локальних інноваційних екосистем, підвищення продуктивності аграрного сектору, поширення сталих технологічних практик та зміцнення конкурентоспроможності регіональної економіки.

Ключові слова: *дослідницькі інфраструктури, трансфер технологій, аграрний сектор, інноваційні екосистеми, смарт-спеціалізація, стале сільське господарство.*

Introduction. In today's world the agricultural sector forms the foundations of global economic stability and food security. At the same time agricultural sector faces growing challenges such as climate change, population growth, resource limits

and changing consumer demand. In these conditions traditional farming methods are becoming increasingly unsustainable. The solution to these problems lies in a paradigm shift that should integrate RIs, promotion of innovations and effective technology transfer to implement new solutions and agriculture practices. This triad forms the basis of sustainable agriculture, ensuring the development of the sector in line with future needs, while maintaining environmental and social well-being.

At the heart of this transformation is the creation of mechanisms for aligning research results with practical application in agriculture. Research infrastructures - Ris (experimental farms, laboratories and digital platforms, living laboratories) are the basis for scientific discoveries and technological progress. In the agricultural sector, infrastructures generate fundamental knowledge about crop genetics, soil health, the effectiveness of precision agriculture and the peculiarities of adaptation to the climate of various objects and living organisms.

World practice, in particular the experience of Ukraine, shows that the presence of advanced research does not guarantee its effective application. Bridging the gap between research and real practice is a complex task, which, in the context of accelerating innovation processes and competition, requires new systems of innovation and technology transfer.

Literature review. According to Silva, Kovaleski, & Pagani (2019) [1] in modern conditions, technology transfer largely depends on the integration between universities, businesses and government agencies. Arenas, & González (2018) [2] note that technology transfer is significantly influenced by the external environment (social, behavioral and legislative factors), as well as the creation of technology transfer centers within individual industries and segments of the economy. Audretsch et al. (2014) [3] [note that the emergence of new technologies acts as a driving force and a stimulating factor of globalization. At the same time, these technologies are changing rapidly, shortening the life cycles of products and the processes underlying them, as well as increasing the cost of technologies. At the

same time, technology transfer by academic and scientific institutions has become a strategic factor for companies and countries to cope with these challenges in the global economy.

Choi Hee Jun (2020) [4] lists a large number of technology transfer models, among which, in his opinion, it is necessary to highlight the most common: the conformity model, the knowledge use model and the contextual cooperation model. Grimaldi, Kenney, & Piccaluga (2020) [5] note the increasing role of universities in the process of technology transfer, as they better take into account regional characteristics and traditions.

Research by Rambe, & Khaola (2021) [6] on the example of developing countries also confirms the presence of direct significant links between innovation and technology transfer; technology transfer and productivity; as well as productivity and competitiveness.

Considering these factors ensures the successful transfer of agricultural technologies, leading to increased productivity and sustainability in the field of agriculture. The progress in science and technology, coupled with the incorporation of advanced technologies in agriculture, requires the execution of projects centered around technology transfer and the establishment of RI.

The unresolved problem within the methodology of research infrastructures for local-based industrial analysis in agriculture lies in the lack of integrated, scalable, and context-sensitive frameworks that effectively connect local data collection with broader analytical systems. Current approaches often fail to capture the complexity of agricultural ecosystems, including variability in environmental conditions, informal practices, and socio-economic factors at the local level. Additionally, there is insufficient standardization in data collection and limited interoperability between research infrastructures, which hinders comparative analysis and evidence-based policymaking. The gap between technological capabilities and their practical implementation in rural areas, especially regarding

accessibility, digital literacy, and resource constraints, further complicates the development of reliable methodologies. As a result, existing models do not fully support accurate, real-time, and locally relevant industrial analysis in agriculture.

The purpose of the study is to develop a methodology for analyzing research infrastructures in the system of locally oriented technology transfer and determine their impact on the innovative development of the agricultural sector.

Methodology. he methodology of this study is a multidimensional and integrated approach to understanding the role of RIs and technology transfer in sustainable agriculture models, taking into account the modern logic of the innovation process. The methodology includes a set of research methods, which allows for a deep understanding of complex interactions, provides both a detailed narrative and measurable indicators.

Main material. In the current conditions of strengthening the role of knowledge and innovation in ensuring the competitiveness of economic sectors, the development of research infrastructures is of great importance. Traditionally, research infrastructures are considered as a set of material and technical resources, equipment, laboratories and scientific institutions that ensure the conduct of fundamental and applied research. At the same time, modern trends in the development of innovation systems indicate the need for a broader interpretation of this concept, in particular in the context of strengthening the interaction of science, business and society, as well as activating technology transfer processes.

Within the framework of this study, an author's approach to the interpretation of research infrastructures is proposed, which is based on their consideration as a multi-component institutional and organizational system that ensures the generation of knowledge, its transformation into technological solutions and effective transfer to the real sector of the economy at the local level. This approach allows us to move away from a narrow understanding of research infrastructures as only a material and technical base of scientific research and to consider them as an important element of

the formation and development of local innovation ecosystems.

Research infrastructures are of particular importance in industries characterized by high dependence on technological innovations and the specificity of the natural resource environment, in particular in agriculture. In this context, they act as a platform for conducting applied research, testing innovative agricultural technologies, adapting scientific developments to regional production conditions, and disseminating knowledge among producers.

The proposed author's approach involves considering research infrastructures as a system of interconnected components.

First, the material and technological component, which includes laboratories, research stations, experimental landfills, agricultural demonstration farms, specialized equipment, and digital platforms for data collection and analysis. This component forms the basis for conducting research, testing technologies, and creating innovative products.

Secondly, the institutional component, which includes regulatory and legal mechanisms for the functioning of research infrastructures, organizational management models, forms of partnership between scientific institutions, universities, enterprises and government bodies, as well as tools for supporting innovation activities and commercialization of research results.

Thirdly, the network component, which involves the formation of stable horizontal and vertical connections between participants in the innovation process. In this case, research infrastructures act as peculiar nodes of innovation networks that unite scientific institutions, agricultural enterprises, startups, development institutes, state authorities and local communities.

Fourthly, the transfer and innovation component, which covers mechanisms for disseminating scientific research results, commercializing technologies, creating innovative products and implementing them in production practice. Such mechanisms may include technology transfer centers, innovation hubs, incubators,

demonstration sites and service platforms for supporting agricultural innovations.

Fifth, a locally oriented component, which involves adapting the activities of research infrastructures to the specifics of a particular region, its natural resource potential, traditional production specialization, as well as strategic development priorities, in particular within the framework of the smart specialization approach. Such an orientation allows for greater relevance of scientific research to the needs of the regional economy and to increase the efficiency of innovation implementation.

Within the framework of the proposed approach, research infrastructures perform several key functions. First of all, this is the generation of new knowledge and technological solutions as a result of fundamental and applied research. The second important function is mediation in technology transfer processes, which ensures effective interaction between the scientific sphere and the production sector. The third function is the activation of local innovation ecosystems, which is manifested in the formation of cooperation networks, stimulating the innovative activity of enterprises and attracting new participants to the processes of creating and disseminating innovations.

Innovation in modern agriculture is more critical than ever, as business models and the sector is witnessing unprecedented technological advances linked to interdisciplinary innovations. Artificial intelligence, robotics and biotechnology have introduced transformative solutions for agriculture. Precision farming, for example, uses GPS technology and sensors to optimize planting, irrigation and harvesting processes, reducing waste and increasing yields. Advances in genetic engineering are enabling crops to be grown that are more resistant to drought, pests and diseases. While these innovations are promising, they also pose significant challenges. Their complexity often requires specialized knowledge, infrastructure and financial investment, which can deter smallholder farmers and stakeholders with limited resources.

In this context, the role of technology transfer becomes paramount, as it is the process by which scientific research is transformed into practical tools, methods or systems that can be used by end-users. The development of the agri-sector involves the dissemination of innovations among farmers, agribusiness, policymakers and other stakeholders. This process is often hampered by a lack of collaboration between research institutions, private enterprises and government agencies. Country experience shows that stakeholders often work in isolation, pursuing their own goals without coordinating efforts or exchanging ideas. Such a fragmented approach undermines the potential of innovation to stimulate sustainable agricultural development.

Stakeholders in the agricultural sector include researchers, farmers, agribusiness representatives, policymakers and consumers, each with unique perspectives and priorities. Researchers and representatives of industrial RIs are focused on creating new knowledge and developing technologies, but they may lack the means or incentives to interact with practitioners. Farmers, as the main end-users of agricultural technologies, often face barriers such as high costs, limited technical skills and inadequate support systems. Agribusiness is driven by profitability, which can lead to commercial interests prioritizing over sustainability. Policymakers responsible for creating an enabling environment for innovation may lack the technical expertise to assess the long-term implications of new technologies. Consumers, whose preferences are increasingly skewed towards sustainable and ethical products, influence market dynamics but are often disconnected from the production process.

The complexity of integrating the interests of the above parties requires the creation of a holistic framework that encourages collaboration and knowledge sharing. In this regard, smart specialization becomes a viable strategy for developing the innovation cycle, starting with the efforts of RIs and ending with the promotion of the ecological product to the consumer. In this study, Smart Specialization will

consider an innovative policy approach that seeks to identify and develop regional strengths while fostering collaboration between stakeholders. In the agri-sector, these initiatives could include an additional smart framework for the sector and its innovation processes. For example, prioritizing specific crops, technologies, or practices that meet local needs and opportunities. Another potential case is that a region with expertise in horticulture could focus on developing advanced greenhouse technologies, while another region with a large amount of arable land could invest in precision agriculture technologies. By leveraging such regional strengths and fostering public-private partnerships, smart specialization can accelerate the adoption of sustainable practices and technologies through collaboration with innovation communities.

One of the most important challenges in the area of combining research, innovation and technology transfer in agriculture is the increasing complexity of technologies. Advanced systems (autonomous tractors and AI-based crop monitoring, etc.) require a high level of technical expertise and infrastructure. Without adequate training and support, farmers will struggle to adopt these innovations. This will lead to a widening gap between technological potential and practical application. To address this problem, capacity-building initiatives should accompany the introduction of new technologies. Training programs, advisory services and knowledge-sharing platforms can help farmers understand and effectively use advanced tools.

The financial aspect of introducing new technologies cannot be ignored. Smallholder farmers, who constitute a significant part of the global agricultural workforce, often lack the resources to invest in expensive equipment or infrastructure. Public and private financing mechanisms (subsidies, grants and microfinance options) are essential to ensure equitable access to innovations. It is important to invent models of co-financing (multiple stakeholders sharing costs and benefits) that can potentially facilitate wider participation in sustainable agricultural

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practices. In addition to technological and financial considerations, the social and environmental aspects of sectoral innovation should be prioritized.

Generallly sustainable agriculture can be defined not only as increasing productivity. It also includes reducing environmental impacts, enhancing biodiversity and promoting equitable livelihoods. Technologies and practices need to be carefully evaluated for their long-term impact on local ecosystems and communities. For example, while chemical fertilizers and pesticides have historically contributed to increased agricultural production, their overuse has in some cases led to soil degradation and water pollution. Integrating organic farming methods, agroecological practices and circular economy principles through the involvement of RIs as an aggregator can mitigate such negative impacts and promote sustainable development.

The analysis of available research shows that the role of policymakers in this transformational approach is indispensable. Governments should create a framework and appropriate regulatory framework that will stimulate sustainable practices, the availability of innovations and their price. This framework should include policies to encourage research collaboration, intellectual property sharing and public-private partnerships as a factor in integrating vectors of research, innovation and technology transfer. Platforms for global knowledge exchange and local cross-border research projects can shape localized innovations.

Thus, the integration of RIs, innovation and technology transfer in agriculture is not just a technical problem, but is also an important socio-economic imperative and a task of national priority. This requires the identification and concerted efforts of all stakeholders, which will allow overcoming obstacles. It is possible to solve the task through such strategies as intellectual specialization, inclusive access to technologies and sustainable development. As a result, the agricultural sector can move towards a future that is sustainable, productive and equitable.

RI is a complex construct that includes both material and social components

aimed at supporting and facilitating scientific activity. RIs in the innovation ecosystem play a key role in promoting innovative development, contributing to research, commercialization and development of new technologies (Fig. 1).

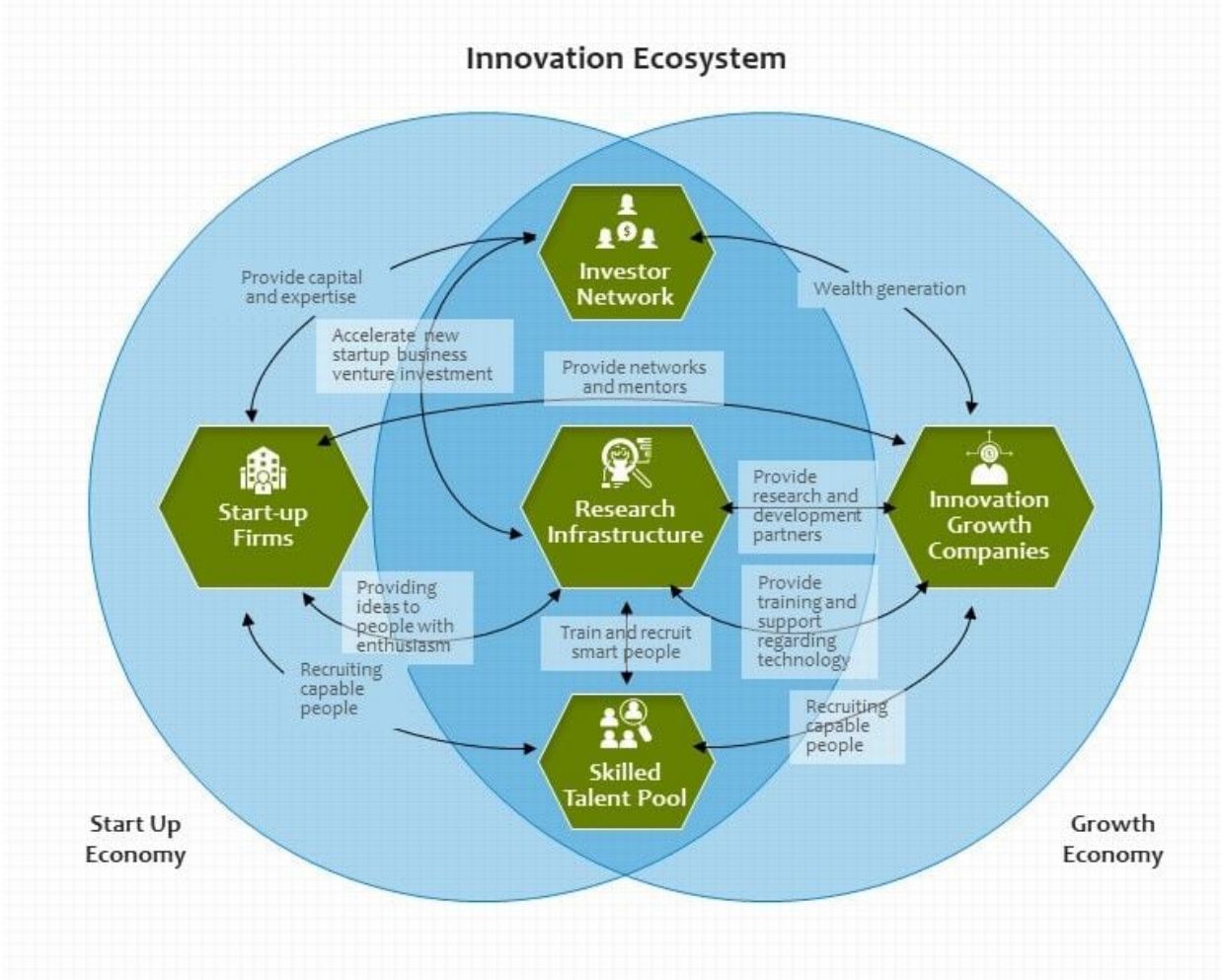

Fig. 1. The place of RIs in the innovation system (Slidegeeks, 2024) [7]

Existing researches examine the benefits of technological advances in agriculture and their techno-economic characteristics. At the same time, a critical gap remains in how these innovations can be effectively transferred and adapted at a specific local level. This is especially important for regions with limited infrastructure and financial resources. The researcher notes that agri-food stakeholders often act in isolation, which leads to fragmentation of efforts and missed opportunities for sustainable development of the sector. In addition, the role

of smart specialization as a strategy for synergy of regional strengths with innovation is insufficiently studied in its application for the development of sustainable agriculture on the basis of the full innovation cycle.

Data collection

The first goal is focused on identifying the contribution of RI to the development of sustainable agriculture and creating an innovative base for the development of the sector. We plan to determine the role played by RIs in conducting adaptive innovative research, knowledge transfer and promoting cooperation between participants in innovation processes. We will pay particular attention to understanding how RIs address local challenges in the context of smart specialization (e.g. soil degradation and resource efficiency) and how they can be incorporated into local development processes. We will also identify how RIs contribute to promoting sustainable agriculture.

The first step in data collection is to conduct a systematic literature review, which provides the theoretical and practical basis for the study. The review involves identifying, selecting and critically analyzing a wide range of scientific articles, policy reports, case studies related to the topics of RI, technology transfer and sustainable agriculture. The literature review should be conducted using established guidelines such as PRISMA (Preferred Reporting Elements for Systematic Reviews and Meta-Analyses). The main sources include peer-reviewed journals, official publications of international organizations, official documents of research institutions and think tanks. The main focus of the analysis is to obtain information on existing frameworks, models and success stories while identifying knowledge gaps that the current study aims to address.

Framework of smart specialization

The innovation process in the context of smart specialization is based on the search for unique competitive advantages of regions and their implementation through innovations. Given the significant role of the agricultural sector in the smart

specialization of the regions of Ukraine, this approach is appropriate in the context of the objectives of this study. The main logic of smart specialization is the concentration of resources in areas that have the highest potential for local growth. This involves the integration of local characteristics, scientific achievements and business into a single cycle of creating and implementing innovations. Smart specialization emphasizes the development of specific sectors that best meet market needs based on the use of the strengths of the region. RIs play a key role in supporting this process. Laboratories, technology parks and innovation centers, etc. provide the scientific basis and necessary technical support for the development of new technologies. They create opportunities for experimentation and testing ideas, facilitating the rapid transition from research to implementation in production. Thanks to these infrastructures, regions can use scientific resources more effectively and attract investments. Technology transfer, in turn, is a critical mechanism that connects research within RIs with the real sector of the economy. It helps to adapt scientific discoveries to the needs of business and the region (community), making them practically usable. Within the framework of smart specialization, technology transfer ensures the creation of new products, increasing the competitiveness of enterprises and expanding access to global markets. Thus, it is through this process that the transformation of intellectual potential into economic development of regions occurs. Identifying problems and gaps in this mechanism is an important task in the context of the development of innovative sustainable agriculture.

Building on this foundation, the study combines the main data collection methods to include fresh ideas and contemporary perspectives. One of the main methods used is semi-structured interviews conducted with stakeholders who play a key role in the development and application of RI and technology transfer in agriculture. These stakeholders include (1) academic researchers, (2) policymakers involved in agricultural development, and (3) farmers who are the end users of these technologies.

Semi-structured interviews

Semi-structured interviews were chosen for the study because of their flexibility. They allow for exploration of key themes while taking into account the unique ideas, concerns and experiences of each participant. The interviews were conducted to uncover the current motivations, challenges and opportunities perceived by these stakeholders, providing a detailed understanding of the factors influencing the effectiveness of RIs and technology transfer. Focus groups were conducted with farming communities to explore the demand-side perspectives. These interviews are particularly valuable for understanding farmers' experiences, including their interactions with research findings and technologies, the challenges they face in implementing innovations, and their recommendations for improvement. Focus groups also help to gather collective perspectives and highlight variations in experiences based on factors such as farm size and farming practices. The findings of these focus groups are crucial to ensuring that the research includes an inclusive and bottom-up perspective.

An important component of primary data collection is the use of structured questionnaires alongside unstructured ones. These surveys were conducted among a target group of practicing farmers and researchers. The structured nature of the surveys allows for the collection of standardized quantitative data that can be statistically analyzed to identify patterns and relationships. The survey questions are designed to cover different aspects of the study: the availability and accessibility of RI, the perceived impact of technology transfer on agricultural outcomes, and barriers to effective implementation.

In addition to interviews, focus groups and surveys, the study includes case studies of successful projects or initiatives that exemplify the effective integration of RI and technology transfer in promoting sustainable agriculture. The case studies are selected based on criteria including geographical diversity to represent different agricultural systems and contexts, scale to cover both small- and large-scale

operations, and type of innovation to incorporate a variety of technological and methodological advances. By analysing these cases, the study aims to identify best practices, success factors and potential pitfalls that can serve as a basis for wider applications.

The study also used field observations to gather evidence on the impact of RI and technology transfer. Observations were conducted in a variety of locations, including research institutions, businesses, and pilot agro-industry projects in communities. Field visits allowed for real-world applications of technology and for assessing the specifics of how RIs function in agriculture. This was useful for examining stakeholder interactions in practice within local development. Observations provide a valuable context and helped to validate insights gained through other data collection methods.

Analyzing the mechanisms and best practices of technology transfer in the agricultural sector

The second goal is focused on analyzing the mechanisms and best practices of technology transfer in the agricultural sector. The research methodology takes into account that technology transfer is a dynamic process that includes the movement of a wide range of objects (innovations, tools, methods and knowledge) from research institutions to end users (farmers and agribusiness). The study takes into account the modern transformation of technology transfer processes, which is carried out on the basis of partnership and the involvement of the potential user of the product (technology) in its development. Therefore, in the study, we will analyze ways to organize technology transfer in the context of the specifics of sustainable agriculture and smart specialization. When developing practical recommendations for the institutional and organizational and economic support of technology transfer, we will try to combine modern tools: partnerships, training programs, consulting services, public-private cooperation and digital platforms. We will consider these tools with an emphasis on EU best practices given the priority of this vector for

Ukraine. Based on the results of the comparative and exploratory study, we plan to identify successful models of technology transfer, which will then be conceptualized in an organizational design at the regional level in the context of smart specialization. An important result of the state of the art study is the identification of factors that contribute to their effectiveness, such as the adaptability of technologies to local conditions, the role of intermediaries, capacity-building efforts, and the participation of end-users in the scientific and innovative process from its initial stages.

Assessing the impact of RI and technology transfer on sustainable development outcomes is a joint objective of the study. The overall objective of the innovation process in the context of the SDG is to impact the environmental, economic and social aspects of agricultural management.

The design of these three impacts is carried out at the initial stage of the innovation process, which is implemented on the basis of RIs. Therefore, they play a key role in the sustainability of innovations in the sector. It is worth noting the different levels of possibilities for assessing these impacts. For the Environmental Impact, indicators are investigated, greenhouse gas emission reduction, soil improvement, biodiversity conservation and water use efficiency, etc. The economic impact is more complex and is assessed by analyzing productivity, financial sustainability, income diversification for farmers and creation of opportunities for added value, etc. The social impact is the most complex. It will be assessed using indicators of improved knowledge dissemination, community engagement, creating equal opportunities and increasing the inclusiveness of the sector, and building innovative communities. Given the above, smart specialization will be most effective for the context of the study as a place-based approach that allows for the selection of priorities, community engagement, building innovative communities, and jointly assessing results and adjusting strategy accordingly.

Conclusions. The study is based on a systematic approach to examining the processes surrounding RIs and technology transfer. The study considers these

processes as a kind of interactor, which determines the possibility of taking into account and the direction of these processes in the goals of sustainable development. According to the results of the study, it is aimed at developing effective recommendations for the development of a sustainable agricultural system based on innovation. These recommendations are aimed at increasing the efficiency of RI and technology transfer mechanisms in the vector of their better alignment with the needs of sustainable agriculture. The process of developing recommendations and policies is based on identifying gaps and problems of participants in the processes surrounding RIs and technology transfer in the agricultural sector. The study involves identifying ideas and proposing institutional strategies for solving these problems. Proposals for the creation of innovation centers, promoting inclusive access to technologies, and integrating the principles of sustainable development into national and regional agricultural policies will be evaluated as hypotheses.

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