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Technology Transfer at the Academic Environment from the Perspective of Knowledge Flow within Open Innovation

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The development of cooperation among entities, within which resources and knowledge exchange go beyond the boundaries of organizations, creates a more open approach. The academic environment and the university, when cooperating, play an important role in the transfer of technologies for increasing economic growth and sustainable development. For this reason, this contribution focuses on the analysis of selected aspects of technology transfer at the Technical University in Zvolen from the perspective of the flow of knowledge within the framework of open access to innovation. The outputs of the Technical University in Zvolen published in the scientific database Web of Science over the past 10 years were used for the evaluation. The generated data on publications from the database were subsequently analysed and a network map characterizing the transfer of technology and knowledge on the academic campus of the selected university was processed using the VOSviewer program version 1.6.20. Based on the analysis performed, it can be stated that the transfer of technologies and knowledge at the Technical University in Zvolen from the perspective of cooperation with other organizations and universities is global.

Keywords: open access to innovation, transfer of technology and knowledge, Technical University in Zvolen, database Web of Science, network map

INTRODUCTION

In recent years, open innovation has played a major role, representing more open approach in which resources and knowledge exchange go beyond organizational boundaries. In this innovation model, the main actor and provider of knowledge is the university (de las Heras-Rosas & Herrera, 2021), which aims to develop cooperation among entities and increase the economic development of the region. Technological progress and its rapid development bring significant challenges in the field of technological and innovation management on the part of universities, which are considered the core of knowledge for research and development (Enkel et al., 2009). The complexity of the exchange and transfer of knowledge within organizations is evolving towards the exchange of knowledge among organizations (Alvarez-Meaza et al., 2020). Therefore, in recent times, the transfer of knowledge, technology and innovation (R&D+i) from universities to industry and society has attracted considerable

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attention. Universities as knowledge integrators are relevant in technology transfer processes (Shmeleva et al., 2021; Padilla Bejarano et al., 2023).

Most theories of university technology transfer assess their relationship between university and industry, or through the Triple Helix (Hayashi, 2003; Etzkowitz et al. 2000). The Triple Helix innovation model focuses on the relationships between universities, industry and government. The Quadruple Helix embeds the Triple Helix by adding the "media and cultural public" and "civil society" as a Fourth Helix. The Five-fold Helix innovation model is even broader and more comprehensive, as it contextualizes the Quadruple Helix and additionally adds the "natural environment of society". The Triple Helix explicitly recognizes the importance of higher education for innovation. Some publications describe the Triple Helix not only as a relationship between the university and industry but also emphasize their role in knowledge-based innovation systems (Bercovitz & Feldman 2006). In addition to the legal, economic and political environment, this model characterizes the internal influences supporting a favorable environment for this type of interaction, which form an innovation system within the university determining the speed and direction of the flow of knowledge (Dalmarco et al., 2019, 2018, 2015; Padilla Bejarano et al., 2023). The Triple Helix emphasizes the production and innovation of knowledge in the economy, so it is compatible with knowledge economy. The Quadruple Helix already supports the perspective of the knowledge society and knowledge democracy for the production and innovation of knowledge. In the understanding of the Quadruple Helix, the sustainable development of the knowledge economy requires co-evolution with the knowledge society. The Five-fold Helix emphasizes the inevitable socio-ecological transition of society and economy in the twenty-first century; therefore, the Quintuple Helix is ecologically sensitive. Within the framework of the Quintuple Helix innovation model, it is also necessary to consider the natural environment of society and economy as a driving force for knowledge production and innovation and thus define opportunities for the knowledge economy. In 2009, the European Commission identified the socio-ecological transition as a major challenge for the future development agenda. Here, Quintuple Helix supports the formation of a win-win situation between ecology, knowledge and innovation and the creation of synergies between economy, society and democracy (Narask, 2025).

The Helix model represents the cooperation characteristic of open innovation, because its role is to spread knowledge in society, academia and the economy within the framework of technology and knowledge transfer. (Bozeman, 2000). Its definition depends on the purpose of research and discipline. Various literary sources distinguish between knowledge transfer and technology transfer (Gilbert & Cordey-Hayes, 1996; Padilla Bejarano et al., 2023). Knowledge transfer is defined as scientific knowledge used by scientists to advance science. Technology transfer is a specific process of knowledge transfer that depends on the form in which societies manage knowledge (Bozeman, 2000; Padilla Bejarano et al., 2023; Bejarano et al., 2023).

The different forms of technology and knowledge transfer between universities and organizations in open innovation depend primarily on the policies and environment in each country (González de la Fe, 2009). In addition to the economic, political and legal

environments that intervene in the innovation system, there are also internal influences in the university that ultimately determine the speed and direction of knowledge flows and their roles in knowledge-based innovation systems. Open innovation is more open approach in which resources and exchange of knowledge transcend organizational boundaries, characterizing the collaborative relationships that exist between universities and organizations. Open innovation is therefore an innovation process based on knowledge flows that intentionally cross the boundaries of the university and organizations. These knowledge flows can mean incoming knowledge to the organization, outgoing knowledge from the organization, or both (a combination of external knowledge sources and commercialization activities). The literature on open innovation has focused mainly on knowledge and ideas that flow from one organization to another, with universities being an essential source of knowledge and valuable ideas for open innovation (Padilla Bejarano et al., 2023; Bejarano et al., 2023).

Therefore, the aim of this research is to identify the impact of technology transfer at the Technical University in Zvolen. The research follows the study by Loučanová, (2025).

METHOD

The main subject of the study is the Technical University in Zvolen (abbreviated as TUZVO). The TUZVO is a modern university that develops creative scientific research and, on its basis, provides education at all three levels of higher education in the European educational and research area. In the system of higher education institutions in Slovakia, it has a unique profile focusing on the forest – wood – ecology – environment complex with an appropriate extension to other technical, natural science, security, economic and artistic areas (TUZVO, 2025).

The main subject of the study are technology transfer at the TUZVO from the perspective of the flow of knowledge within open innovations in the context of technology transfer areas, cooperation and their impacts in the field of research carried out at the subject under study.

The aim of the research was to identify the impact of technology transfer on the TUZVO. The research is targeted to the outputs of publications in the WOS database with TUZVO affiliation. The research methodology is based on quantitative data from the WOS database and cluster analysis. Cluster analysis is a quantitative form of classification (King, 2002). Secondary data from WOS are subsequently processed using VOSviewer. VOSviewer is a software for creating and visualizing bibliometric networks. It represents the most modern technique for creating network clustering – cluster analysis of bibliographic data of the researched subject - TUZVO. The study methodology took place in several phases (see Table 1):

Phase I. A literature review characterizing university technology transfer was prepared using the analytical-synthetic method. As part of the analysis of the literature review, objective facts about the issue of technology transfer at universities were examined. Within the studied phenomenon, objects, phenomena and processes were analyzed, breaking them down into individual elements, or rather parts, examining their mutual relationships.

Phase II. Based on the processed literature review, the main goal of the research was defined as follows:

Analysis of technology transfer at the TUZVO based on the concept of open innovation consisting in the exchange of knowledge through the Web of Science (abbreviated WOS) scientific output database over the past ten years (identify the impact of technology transfer at the TUZVO).

In this phase, the research focused on selecting data from the Web of Science scientific output database using the following criteria:

- TUZVO's affiliation with outputs recorded in the WOS scientific database,
- the period of outputs and responses from 2014 to 2024.

The criteria for selecting a publication in the database were the affiliation of at least one author of the publication with the TUZVO and the year of publication during the 2014–2024 period. The WOS database was selected for the analysis of technology transfer data at the TUZVO because it is one of the most important sources of scientific information (Jílek & Clovis, 2018). The WOS is a paid access platform providing access to several bibliographic and citation databases (responses) that provide reference and citation data from scientific journals, conference proceedings and other documents from various scientific fields. It is used to measure, evaluate and monitor scientific research (CVTI, 2024; Berkle et al., 2020).

Phase III. Analysis and interpretation of findings is based on analytical tools of the Web of Science database according to previously established criteria and subsequent analysis of databases obtained from WOS via VOSviewer version 1.6.20. The processed VOSviewer network maps were processed based on three main parameters characterizing technology transfer of the TUZVO:

- keywords of publications,
- co-authorship of publications by countries collaborating on research,
- citations (responses) to publications by countries, which represent the impact of TUZVO research publications.

The created network maps characterize the parameters studied with the highest occurrence. The size of the circle related to the parameter studied is proportional to the frequency of occurrence (number of TUZVO research publications in which the keyword occurs, or the number of co-authorships, citations – responses in given countries). In the network, the degree of similarity that they may have with other parameters studied is also shown using lines. Keywords, or countries, stand out in the network (Padilla Bejarano et al., 2023).

Table 1
Overview of study methodologies

Phases	Name	Description
I.	Literature review	Processing of a literature review focused on university technology transfer and topics related to the categories or conceptual axes of the study – analysis of articles and studies.
II.	Defining the research objective	Analysis of technology transfer to the TUZVO based on the concept of open innovations consisting in the exchange of knowledge through a database of scientific outputs.
	Identification	WOS database of scientific outputs of TUZVO for the last 10 years Period = 2014-2024
	Screening	Database of TUZVO publications in WOS for the given period N=2762
		Database of citations to the TUZVO outputs in WOS for a given period N=23085
III.	Included	Analysis and interpretation of findings

FINDINGS

Based on the theory of the Triple Helix innovation model and its evolutionary models, which recognize the importance of higher education for the development and transfer of knowledge-based innovations, TUZVO technology transfer was analyzed during the 2014–2024 period. During this period, 2762 publications and 23085 registered citations (21353 without self-citations) were published with the affiliation of TUZVO (see Figure 1). The number of publications is stable in the range of 200 to 300 publications per year. Citations have recorded a positive development, which is growing exponentially, thereby increasing the impact of the transfer of knowledge-based innovations of TUZVO.

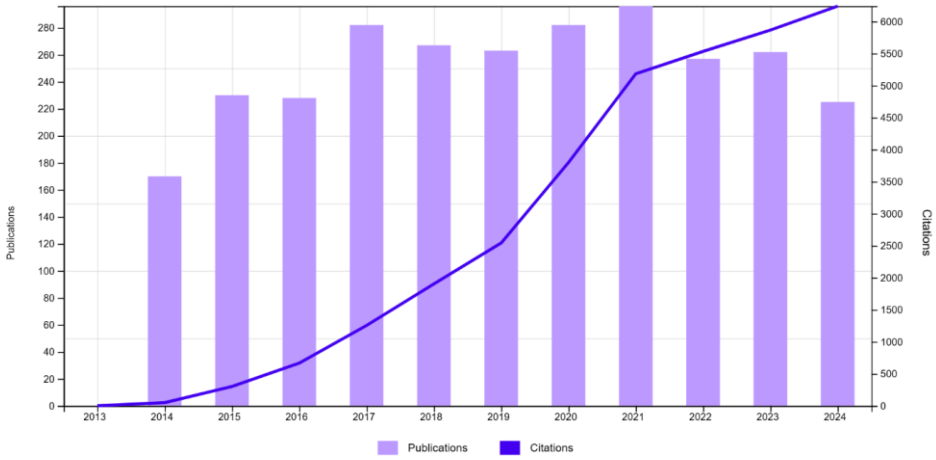

Figure 1
Basic statistics of Technical University in Zvolen in the WOS database
Source: Web of Science, 2025

The research areas that the TUZVO focuses on are forestry, materials science, paper, wood, economics, environmental sciences, ecology and other areas. Based on the identified research focus areas, a network map was subsequently created (see Figure 2), which shows the keywords with the highest occurrence in the research area. The size of the circle associated with a keyword is proportional to the frequency of occurrence (the number of documents in which the keyword occurs). In the network, the degree of similarity that they may have with other keywords is represented by lines. Words that occur most frequently in TUZVO scientific publications stand out on the network map. From the perspective of the keywords of the TUZVO research, 7 clusters were identified; (where 10321 keywords were analyzed, with a minimum occurrence of 5 keywords, and 727 keywords met the threshold of a minimum number of 5). The identified clusters can be generalized. The clusters are focused on forestry, wood, management, biodiversity, climate change, systems, Industry 4.0, calculations related to energy consumption, conductivity, thermal condensation, do not exclude innovations in these areas of research.

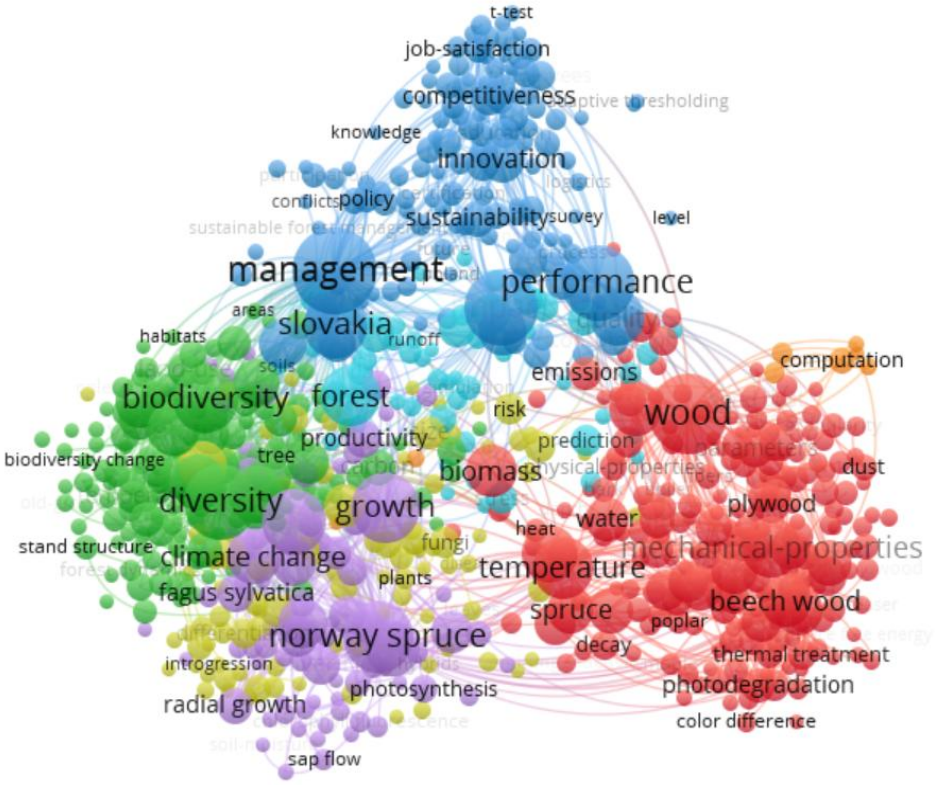

Figure 2
Network map of keywords of publications of the Technical University in Zvolen according to the WOS

The network map of countries with which the TUZVO cooperates in the framework of technology and knowledge transfer (see Figure 3) shows the countries where the TUZVO participates in the framework of co-authorship of research and development results with the highest incidence. From the perspective of cooperation in the transfer of technology and knowledge (from the perspective of co-authorship of research) of the TUZVO, based on the WOS database with individual countries of the world, 110 countries were identified with which the TUZVO has demonstrated co-authorship with other countries in the world. The TUZVO has a representation of cooperation in the framework of co-authorship of publications on all inhabited continents of the world.

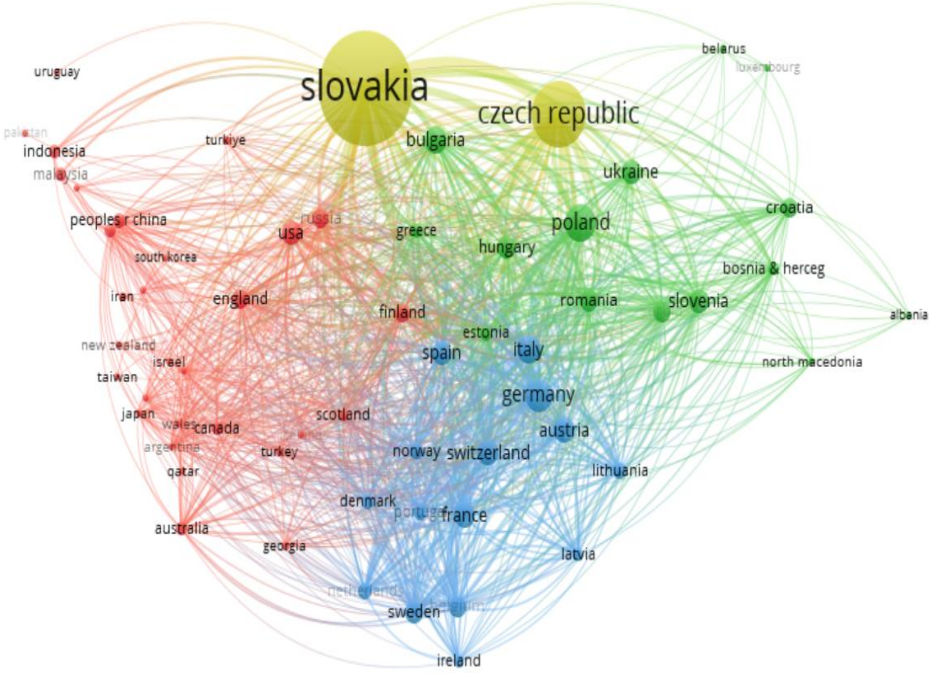

Figure 3
Network map of co-authorship in publications of TUZVO according to the WOS database from a country perspective

The impact of technology and knowledge transfer in terms of citations on the research work of the TUZVO by country is large. 110 countries were identified that cited the results of science and research of the TUZVO (see Figure 4). The impact of technology and knowledge transfer of the TUZVO in terms of citations (responses) of its scientific outputs is extensive, as it is on all inhabited continents of the world.

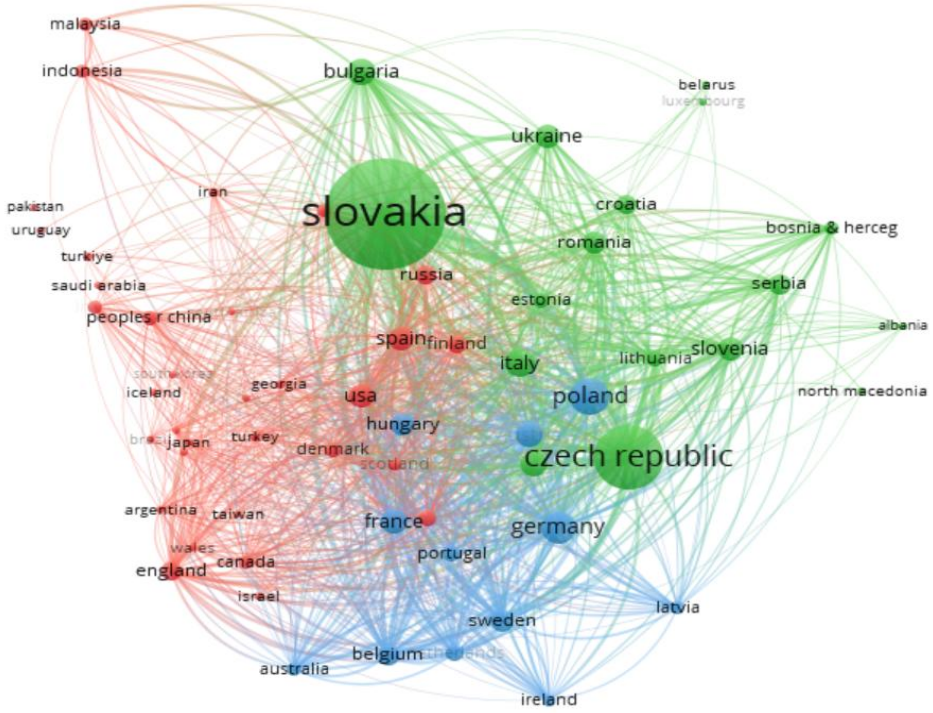

Figure 4
Network map of citations (responses) of publications of the Technical University in Zvolen according to the WOS database from the perspective of countries

DISCUSSION AND CONCLUSION

To examine the parameters of technology transfer of TUZVO from the perspective of knowledge flow within open innovations, a comprehensive analysis was performed on 2762 scientific publications registered in the WOS database over the past 10 years. Through this analysis, 7 key areas of technology transfer were identified: forestry; woodworking; management; biodiversity; climate change; systems, industry 4.0 nd areas related to the solved problem, such as calculations to energy consumption, conductivity, thermal condensation, do not exclude innovations in these areas of research. The analyses also highlighted the importance of knowledge flows as a source of dynamic capabilities (Bogers et al., 2019; Huizingh, 2011;, Igartua et al., 2010; Priyono & Hidayat 2022; Bejarano et al., 2023) and their contribution to the relationship between universities and organizations (Debackere & Veugelers, 2005). There were 110 identified countries in which TUZVO demonstrated co-authorship, and citations (responses) to publications are in all inhabited continents of the world. In this area of technology transfer, mainly domestic influence has been demonstrated, which gradually decreases with distance, although this is not a rule and is not confirmed by the

analysis. In relation to the impact of technology and knowledge transfer, TUZVO has an H-index of 64 in the monitored period of the last 10 years (the H-index indicates how many articles by a given author have a number of citations higher or equal to the article's serial number in the order of the number of citations). Within the framework of the above findings, it can be stated that the TUZVO is trying to develop the transfer of technology and knowledge within the framework of the Quintuple Helix innovation model. The TUZVO focuses on all areas of the Quintuple Helix and, through its profiling, also fulfills its mission as a "green university", which is rooted in the traditions of the Mining Academy in Banská Štiavnica, one of the oldest technical and forestry universities in Europe and the world. The strategic aims of the university, which is defined in the TUZVO Long-Term Plan for 2024 - 2030 with a vision to 2040, are:

- ensuring the quality of all activities,
- effective management,
- sustainable development of infrastructures,
- competitiveness and employability of graduates,
- internationally acceptable outputs of scientific research and art,
- innovation and technology transfer,
- social and environmental responsibility,
- building a positive image of the university (TUZVO, 2025).

The sustainable development of infrastructures, technology transfer and sustainable innovation promote green growth, which in turn positively impacts economic growth. Green growth refers to the production of green technologies that are environmentally friendly (Wiebe & Yamano, 2016). Green growth is an acceptable strategy to control environmental degradation (Guo, Qu, & Tseng, 2017; Sandberg, Klockars, & Wil, 2019; Fernandes et al., 2021). Within the framework of the green growth strategy, strengthening foreign support for scientific research and the ability of innovators to absorb technological transfer and knowledge are important to improve the efficiency of green technology innovation (Zhu et al., 2021).

In relation to absorptive capacity, several authors state that the expected benefits in the field of technology transfer within open innovation are not guaranteed and depend on the ability of organizations to accept and adapt new knowledge (de las Heras-Rosas & Herrera, 2021; Cohen, 1990; Zahra, 2002; Lane et al., 2006; Bogers & Lhuillery 2011). These results support the concept of goal and quality setting theory in an academic setting (Sides & Cuevas, 2020; Yusuf, 2023). Research generally suggests that organizations must be ready to assimilate new information and benefit from its application. Analyses of the relationship between open innovation and universities identified that research based on the connection between universities, businesses and collaboration was mainly associated with topics such as entrepreneurship, analyses of different Helix models or commercialization. These connections with knowledge transfer methods have a motivating effect for the university. (de las Heras-Rosas & Herrera, 2021). Therefore, for a successful transfer, it is essential to create new partnerships within the TUZVO. Technology transfer based on partnerships in the academic sphere is a complex process that can be effectively supported by an open innovation approach. In addition, technology and knowledge transfer have been

identified as an important link for long-term sustainability (Almutairi et al., 2025), globalization and the need for innovation (Chalkiadaki, 2018) in increasing environmental awareness (Aliman & Astina, 2019).

The open technology transfer of TUZVO represents, at the regional and global level (impact up to 110 countries around the world), a key channel for the use of knowledge. From the perspective of the technology transfer and innovation strategy, the university should focus on a diversification strategy, i.e. to focus on its strengths and minimize threats. The goal is to maximize its strongest point, which is experienced employees, capable of creating innovations and solving real problems from practice and developing further research and administrative personnel capacities in accordance with the positive transfer theory and scaffolding (Báliková & Šálka, 2022; Alfin et al., 2019). The greatest threats that affect the university are mainly associated with legislative and financial barriers in public policy, innovation policy and the transfer of scientific knowledge into practice, as well as barriers on the part of businesses. Despite this, it is important to deepen cooperation and create new partnerships with entities from economic practice and so achieve a more effective transfer of scientific knowledge into practice. It is necessary to create values in the field of continuing education in order to replace the traditional linear economy with an open approach to innovation (Qu et al., 2022). From the perspective of the TUZVO, it is important to focus on external marketing in this area. The university should make the outputs of its cutting-edge research more visible and popularize them and create an effective offer for institutions of economic and social practice, thereby minimizing the threats that affect it.

Technology and knowledge transfer in academia is a process in which the results of research and innovation from academic institutions are transferred into practice, especially in industry and business. This process supports the creation of new technologies, products and services that have the potential to improve competitiveness and efficiency in various areas. For successful transfer, it is essential to create strong partnerships between universities and other organizations and universities. The aim this of the research was to identify the impact of technology transfer on the TUZVO. As the work carried out shows, technology transfer to the TUZVO significantly contributes to technological progress and the development of society. The orientation of technology and knowledge transfer is mainly oriented towards the areas of forestry, wood processing, environmental science, sustainability and other areas related to university research. Technology transfer in academia is a complex process that can be effectively supported by an open innovation approach. This innovation model allows for better connections between universities and other organizations within the framework of research and innovation, which increases the flexibility, speed and efficiency of technology, knowledge and innovation transfer. However, this process is associated with various challenges that need to be identified and incorporated into further development strategies, which can be the focus of further research. The limitations of this study are mainly in the data database, which focused on the largest scientific database WOS. Therefore, future research will focus on the analysis and identification of technology transfer on the TUZVO with multiple databases.

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