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INVENTING THE FUTURE: CAN BULGARIAN UNIVERSITIES FULFILL THEIR MISSION AS CATALYSTS FOR ECONOMIC GROWTH AND SUSTAINABILITY?

Dr. Ralitsa Zayakova-Krushkova, Assist. Prof.,
Dr. Alexander Mitov, Assoc. Prof.
Technical University – Sofia

Abstract. Universities play an indispensable role in the global innovation ecosystem, not only as centers for generating and disseminating knowledge but also as key actors addressing societal challenges through sustainable and transformative innovation. The transition from academic research to market-ready solutions is facilitated by Technology Transfer Offices (TTOs), which serve as intermediaries between academia and industry. This paper examines the dual role of TTOs in the European Union (EU) and Bulgaria, focusing on their approaches, methodologies, challenges, and opportunities. It introduces the concept of "synergetic individuality," emphasizing how universities can leverage their unique strengths to foster innovation while adapting to market demands. Based on the Karlsruhe Institute of Technology (KIT) innovation strategy as one of the best-practice examples, the European Patent Office's (EPO) 2024 study, the National Innovation Strategy for Smart Specialization 2021 – 2027, and the patent search results of a Bulgarian university patent activity, this article provides a comparative analysis of Bulgaria's performance in knowledge transfer. Special emphasis is placed on the potential for collaboration between technical and economic universities to overcome systemic gaps in commercialization. Recommendations are provided to enhance the effectiveness of Bulgarian TTOs and align their practices with European standards.

Keywords: Technology Transfer Office; synergetic individuality; university-business collaboration; intellectual property; innovation ecosystems; Bulgaria; AI; methodology for TTOs work

Introduction

"Innovate or die." This timeless insight from Peter Drucker ("Innovation and Entrepreneurship", 1985) underscores the urgency for organizations to adapt, innovate, and thrive in an increasingly competitive global economy. For universities,

this call to action resonates deeply and is particularly relevant as they navigate the dual responsibility of advancing knowledge and contributing to socio-economic development. In addition to their traditional missions of education and research, universities are now recognized as engines of innovation, social transformation, driving economic growth through research commercialization and long-term collaboration with industry.

One of the key missions of universities is the creation of transformative innovations – those capable of driving radical changes in existing industries, social structures, or technologies. Transformative innovations introduce new paradigms, completely alter processes, or lead to the creation of entirely new markets. They aim to transform entire systems – whether economic, social, or technological – with the goal of achieving profound and long-term impact. Although they require significant resources and time to develop, they are innovations that can influence all industries. Examples of transformative innovations include artificial intelligence, the internet, and electric vehicles.

Conversely, universities also play a significant role in developing transferable innovations. These are innovations ready for implementation and adaptation across various environments or contexts. While not revolutionary, they hold high practical value and address specific problems. They are typically simpler to implement, involve lower risks, and provide quick returns on investment. Examples include specific AI applications, such as demand forecasting software in manufacturing, adaptable for different companies.

This dual role highlights the unique position of universities in the innovation process, namely not only to create knowledge and technologies with transformative potential but also to offer practical solutions to current social and economic challenges.

However, this potential often remains unrealized without structured mechanisms to facilitate the transfer of academic research to market-ready solutions.

The "gap" between one's own research and its implementation in everyday life, at the very heart of society, is familiar to almost everyone working in academia. During the course of a scientific career, the question often arises: what are the possibilities for making the results of scientific work accessible to a broader audience? In times of rapidly growing knowledge, publications in scientific journals or presentations at scientific forums are not the only – and certainly not always the most reasonable -ways to disseminate new knowledge.

Drawing on insights from institutions such as the Karlsruhe Institute of Technology (KIT) and its "Research to Business" online platform or as Université Paris-Saclay (France), known for its interdisciplinary research capabilities and extensive collaboration with Thales to develop AI-driven solutions for national security, this article explores how systemic challenges in technology transfer can be addressed. The article does not aim to provide definitive solutions but rather seeks

to contribute to the ongoing dialogue by presenting practical ideas and frameworks that Bulgarian universities can adapt to their unique contexts. By examining best practices bridging "the gap" and aligning with strategic goals, Bulgarian universities could strengthen their role both at the national level and within and within the European innovation ecosystem.

1. The Concept of Synergetic Individuality in Universities

"The best way to predict the future is to invent it," said Alan Kay (paraphrasing Abraham Lincoln's thought that "the best way to predict your future is to create it yourself"), emphasizing the transformative potential of universities.

Synergetic individuality refers to the unique identity of each university, shaped by its geographic location, research expertise, and socio-economic context. This individuality enables universities to differentiate themselves within the innovation ecosystem, leveraging their strengths to drive impactful research and societal change.

McCowan (2020) highlights that universities can act as "pivotal agents of change," promoting sustainability and social progress through transformative science and interdisciplinary collaboration. Synergetic individuality emphasizes that each university must harness its strengths while maintaining openness to collaboration with industry and other stakeholders.

From this point of view, the concept of synergetic individuality captures the ability of universities to leverage their unique strengths and align them with societal and market needs. This involves tailoring their research priorities, industry collaborations, and innovation strategies to their institutional strengths and regional context. Key dimensions include:

– Specialization: Universities focusing on niche areas that can attract targeted industry partnerships.

– Regional Integration: Universities surrounded by industrial or technological centers, which are better positioned for collaborative innovations in the regions.

– Sustainability Alignment: Universities that prioritize sustainability in their research and commercialization efforts contribute to long-term societal benefits.

2. Insights of the European Best Practices

2.1. The European Context: Uneven Patent Activity and Innovation Disparities

The European Patent Office (EPO Report, January 29, 2024) reports that 69% of all patent applications in European countries were filed by large companies, while 23% were filed by SMEs and individual inventors, and only 8% by universities and public research organizations (PROs). Despite being one of the primary ways through which universities realize their "third mission" (after teaching and research), patenting activity remains relatively low for universities in Europe. Fur-

thermore, less than 10% of patents are jointly filed by universities and businesses, reflecting a persistent disconnect between academia and industry.

Further, according to research results from a RETHINK-GSC study (Project 'Rethinking Global Supply Chains: Measurement, Impact and Policy'), led by the Kiel Institute in cooperation with Gdańsk University of Technology, the European university patenting is highly concentrated geographically. The research data shows that 72% of all patent applications filed between 1980 and 2019 at the world's five largest intellectual property offices (known as the IP5: the Korean Intellectual Property Office (KIPO), European Patent Office (EPO), Japan Patent Office (JPO), China National Intellectual Property Administration (CNIPA) and United States Patent and Trademark Office (USPTO) are coming from just five Western European countries (UK, Germany, France, Belgium, and Switzerland). Strikingly to the researchers, over 70% of European universities report no direct patent activity at all. Furthermore, the international patenting position of European universities is also relatively weak. The world's top 50 patenting universities are dominated by educational institutions in the United States (18 universities), China (18 universities), and South Korea, underscoring Europe's lag in global competitiveness.

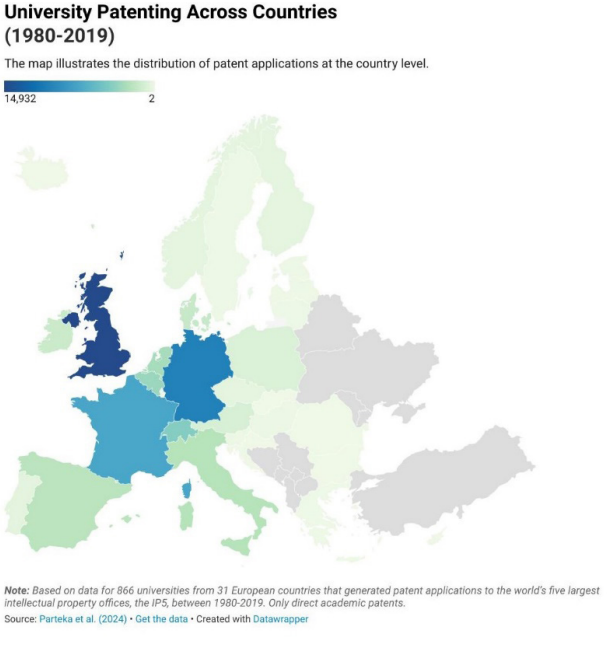

Figure 1. University patenting across countries (1980 – 2019)

This uneven distribution raises concerns about Europe's ability to translate academic research into commercial success. According to the RETHINK-GSC study these disparities highlight the need for balanced policies that reduce regional innovation gaps while empowering leading universities to compete globally.

Top Five European Patenting Universities (1980 – 2019) as per the study are:

1. University of Oxford: 1,953 patents
2. University College London: 1,782 patents
3. Federal Institute of Technology Lausanne (EPFL): 1,410 patents
4. Federal Institute of Technology Zurich (ETH Zurich): 1,225 patents
5. Imperial College London: 1,192 patents

Despite Brexit, universities like Oxford and Imperial College London continue to lead patenting efforts, but no EU university currently features in the top rankings. As stated by Parteka et al., the researchers of the RETHINK-GSC project, this lack of patenting activity further contributes to the so-called "European paradox," where Europe excels in producing high-quality academic research but struggles to translate this knowledge into market-ready innovations.

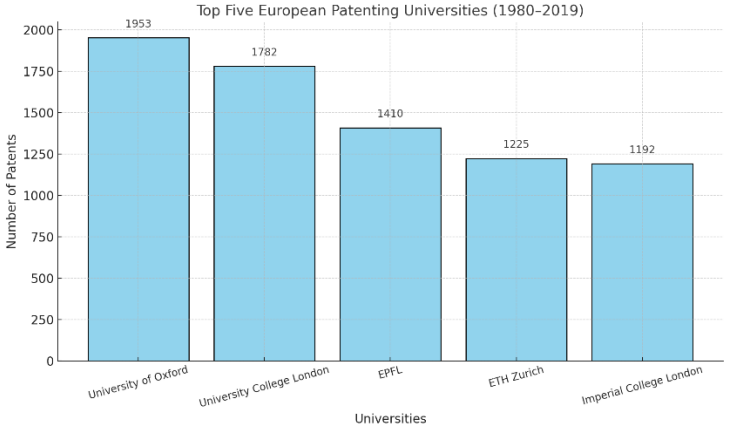

Figure 2. Top five European patenting universities (1980 – 2019)

Bulgaria is underrepresented in the study, with only two patenting universities out of 51 universities included in the study, placing our country lower in the ranking (31st place) among European nations.

2.2. Lessons from Karlsruhe Institute of Technology and Université Paris-Saclay

Case of Karlsruhe Institute of Technology (KIT), Germany

The selection of the Karlsruhe Institute of Technology (KIT) as an example in the

present article is a result of an extensive analysis of intellectual property strategies, policies, and practices across various European universities, showcasing its exemplary model for fostering innovation and technology transfer. KIT exemplifies the concept of synergetic individuality through its strategic alignment of academic research, industry collaboration, and entrepreneurship.

KIT's "Research to Business" strategy integrates interdisciplinary expertise and market-oriented practices to foster impactful innovations. The following elements illustrate how KIT leverages its unique strengths:

1) Intellectual Property (IP) and Licensing Success:

In 2023, KIT filed 38 patent applications, of which 65% are actively utilized in licenses or research and development (R&D) contracts. This high exploitation rate highlights KIT's ability to align its IP portfolio with industry needs, creating opportunities for commercialization and revenue generation. The remaining 35% of the portfolio is used strategically in publicly funded projects, ensuring long-term research relevance.

2) Comprehensive Innovation Ecosystem:

oKIT's IP contracts totaled 458 agreements in 2023, including licenses and technology transfer agreements, generating revenues that vary from small-scale projects to significant industrial collaborations. These revenues underscore the importance of maintaining a diversified innovation portfolio that supports both exploratory and applied research.

3) Entrepreneurial Support Through Start-Ups:

KIT's Gründerschmiede program focuses on fostering entrepreneurial skills among students and researchers, resulting in a robust start-up ecosystem. The KIT's program includes tailored services, events, and partnerships with national and local networks. This initiative has made KIT a flagship institution for start-up support, achieving a record number of 50 spin-offs in 2019 and continued success in subsequent years.

4) Holistic Innovation Strategy – KIT 2025:

As part of its KIT 2025 *"umbrella strategy"*, KIT is gradually introducing measures to strengthen its innovation framework. These include expanding investment management to support young companies, professionalizing spin-off development, and creating a structured approach to long-term industrial collaboration. This strategy exemplifies how universities can institutionalize synergetic individuality to sustain their competitive edge.

Case of Université Paris-Saclay, France

Another good example of synergetic individuality is the approach of Université Paris-Saclay, which has established a robust partnership with Thales, focusing on interdisciplinary research and innovation, particularly in areas pertinent to national security. This collaboration is exemplified by the Laboratoire Albert Fert, a joint research unit involving the CNRS, Thales, and Université Paris-Saclay. The laboratory concentrates on

condensed matter physics, including spintronics, superconductivity, and neuromorphic physics, aiming to develop applications that enhance information and communication technologies, unconventional computing methods, and quantum technologies.

Additionally, Université Paris-Saclay is a participant in the RESQUE consortium, a French initiative led by Thales. This consortium is dedicated to developing post-quantum cryptography solutions to secure communications and networks against potential quantum computing threats. The project underscores the university's commitment to advancing cybersecurity measures in collaboration with industry leaders.

These collaborations highlight Université Paris-Saclay's interdisciplinary research capabilities and its active role in developing advanced technologies in partnership with industry leaders like Thales, contributing significantly to national security and technological innovation.

The experience of KIT and Université Paris-Saclay demonstrates how universities can balance their core research missions with industry needs, achieving a synergistic relationship between academia and business. Bulgarian universities, while operating in a different socio-economic context, can draw inspiration from such practices by:

– Proactively managing their IP portfolios for commercialization.

– Establishing dedicated start-up promotion programs.

– Creating long-term innovation strategies that integrate research and market-driven objectives.

The experience of KIT and Université Paris-Saclay is not a universal model but rather an example of how universities can craft unique strategies to strengthen their impact within the global innovation ecosystem. The KIT and UPS lessons can serve as inspiration for Bulgarian universities seeking to enhance their innovation and technology transfer processes.

3. Challenges for Bulgarian Universities

Bulgaria's National Innovation Strategy for Smart Specialisation 2021–2027 provides a critical framework for guiding universities and businesses to align their strengths and research priorities with national and European goals. It emphasizes sectoral policies in areas such as the green economy, digital transformation, space policy, and defense sector, all of which are essential for driving Bulgaria's economic growth and integration into the EU innovation ecosystem.

Despite the existing roadmap set by the National Innovation Strategy, for Bulgarian universities achieving synergetic individuality is often hindered by systemic challenges:

– *Limited Financial Resources*: Public and private investment in research and development (R&D) remains low, with Bulgaria spending only 0.8% of GDP on R&D compared to the EU average of 2.3%.

– *Underutilized Opportunities for Licensing*: Unlike KIT, where 65% of patents are under active licensing or R&D contracts, Bulgarian universities have not capitalized on their IP portfolios.

– *Cultural Barriers*: Many researchers lack incentives to prioritize commercialization over traditional academic outputs (e.g., scientific publications).

– *Fragmented Ecosystem*: Poor coordination between academia, industry, and government hinders technology transfer.

– *Weak IP Culture*: Many researchers lack awareness of IP protection and commercialization processes.

– *Fragmented Efforts*: Universities often lack strategic coordination, operating in silos that hinder interdisciplinary innovation.

– *Policy and Bureaucratic Barriers*: Regulatory hurdles impede the formation of university-industry collaborations and the commercialization of research outputs.

– *Lack of collaboration between the universities*: for instance, while technical universities excel in research, they often lack the expertise and networks needed for effective commercialization. Bridging this gap through partnerships with economic universities, for instance, can significantly improve Bulgaria's innovation output.

– *Lack of Specialized Expertise in TTOs:* TTOs often operate with limited staff who may not have specialized training in IP management, business development, or commercialization. This is particularly evident in universities focused on technical and natural sciences, which cannot afford to hire business experts.

– *Brain Drain:* Many Bulgarian researchers leave for better opportunities abroad, reducing the country's innovation capacity.

– *Low Visibility in International Innovation Networks*: Bulgarian universities are underrepresented in international patent databases and major R&D collaborations, which limits their ability to attract foreign partners and investors.

– *Weak Market Demand for University Innovations*: Many industries in Bulgaria lack the resources or innovation culture to engage in collaborative R&D with universities. As a result, academic research often remains disconnected from practical market needs.

The challenges faced by Bulgarian universities in fostering innovation and effective knowledge transfer are starkly reflected in their patent activities. The results of the patent search carried out by the authors within the patent database of the Bulgarian Patent Office regretfully reveal minimal patenting activity by Bulgarian universities.

A total of 108 patent documents were identified in the period 2004 – 2024. Only 40 of them are active patents. It is appropriate to note that 50% of them are possessed by the Technical University – Sofia), while 9 are under substantive examination (also mainly filed by the TU – Sofia). Only a few of the active patents are owned jointly by universities and individuals (inventors), with just one patent co-owned by a university and a company. A total of 120 utility models were identified, 83 of which are active as over 20% of which are held by TU – Sofia. Compared to patents, there is a number of utility models co-owned by several universities or co-owned by a university and the Bulgarian Academy of Sciences (BAS). However, again, only one utility model is jointly owned by a university and a business corporation. From Espacenet

and Eporeg databases within the same search period, only seven patent documents were identified where the applicant/patent holder is a Bulgarian university. Of these, one (with applicant TU – Sofia) is in the stage of substantive examination, while the remaining patents have been rejected, withdrawn or terminated due to non-payment of granting a patent or annual maintenance fees.

The aforementioned findings highlight the need for Bulgarian universities to adopt strategic measures for improving their IP policies, for managing the invention development, for strengthening the role of their TTO structures, and for fostering industry partnerships.

4. The Role of Technology Transfer Offices (TTOs)

The transition of academic research outputs to market-ready solutions is facilitated by Technology Transfer Offices (TTOs), which act as intermediaries between academia and industry. The transition into practical implementation of research outputs is a complex process requiring structured mechanisms and expertise. TTOs are specialized units responsible for managing the entire technology transfer process, from identifying research with commercial potential to securing partnerships with industry.

Organizational Structure of TTOs

The organizational structure of TTOs typically follows a two-tier model designed to efficiently bridge the gap between academic research and societal or market needs.

The first tier comprises **specialized teams** of professionals with expertise in key areas such as law, marketing, and technology scouting. These teams are responsible for managing the full lifecycle of technology transfer, from identifying promising innovations to negotiating intellectual property rights and facilitating commercialization. The second tier involves **advisory boards**, which include representatives from industry, government, and other stakeholders. These boards play a critical role in aligning the strategic direction of the TTO with broader societal and market priorities, ensuring that academic research addresses real-world challenges and opportunities.

While this two-tier model is widely adopted, variations may exist depending on the university's size, focus, and regional practices. Nonetheless, this structure provides a robust framework for fostering innovation and maximizing the impact of research outcomes.

Core Functions of TTOs

TTOs are widely regarded as the operational backbone of technology transfer, overseeing the entire lifecycle of research commercialization. Their core functions encompass the following key areas:

1. Intellectual Property (IP) Management: This includes filing patent applications, securing copyrights, and negotiating licensing agreements to protect and commercialize academic research outputs.

2. Industry Engagement: TTOs play a pivotal role in building strategic partnerships with companies, facilitating joint R&D projects, consultancy services, and technology licensing.

3. Start-Up and Spin-Off Support: Assisting researchers in establishing start-ups and launching spin-offs to commercialize their innovations.

4. Revenue Generation: By negotiating licensing deals, TTOs generate income for universities through royalties, licensing fees, and equity stakes in spin-offs, thereby contributing to the sustainability of innovation ecosystems.

5. Comprehensive Methodology for Bulgarian TTOs

To optimize their impact, TTOs must implement a multifaceted methodology that harmonizes proactive supply-side strategies with industry-driven demand. This approach relies on integrating advanced digital tools, fostering collaborations, and maintaining adaptive feedback mechanisms, ensuring sustainable and impactful innovation transfer.

The **active supply model** underpins proactive initiatives to commercialize university research outputs through a structured process. Central to this model is the establishment of interdisciplinary teams that identify research results with significant commercialization potential. These efforts involve early-stage discussions facilitated by technology scouts with business expertise, ensuring that research outputs are aligned with industry needs. Technologies are also assessed for their market readiness and technical feasibility. For Bulgarian universities, aligning TTOs' methodologies with sectors prioritized in the national innovation strategy – such as green energy, digital transformation, and healthcare – strongly advisable.

To enhance visibility and accessibility, universities must adopt centralized digital platforms to showcase research achievements, patents, and ongoing projects. These platforms enable businesses to identify tailored R&D solutions, request customized research, or explore licensing agreements. Promising innovations can then be validated through pilot testing, providing critical insights into their technical and commercial viability. Following validation, intellectual property management, tailored licensing strategies, and spin-off creation streamline the pathway from innovation to market. Universities should also collaborate with economic institutions to design and negotiate customized licensing agreements, further enhancing commercialization outcomes.

The **active demand model**, in contrast, focuses on responding to specific challenges and needs identified by industry stakeholders. This model emphasizes close collaboration through innovation challenges and sector-specific forums where companies present pressing problems that inform university research priorities. Contract research agreements formalize these collaborations, allowing universities to deliver targeted solutions. Additionally, advisory and consulting services provide long-term implementation support, ensuring the seamless adoption of developed technologies.

Examples of this model include collaborative R&D projects in areas such as green hydrogen production, which can contribute to Bulgaria's decarbonization goals under the EU Green Deal, and microelectronics or space navigation systems, which are strategically important for the digital economy. By leveraging EU co-funded programs

like Horizon Europe, ERA-NET, etc. TTOs can further expand the scope and impact of such initiatives.

Achieving a balance between these two models requires a nuanced and integrated approach. Interdisciplinary collaboration with public research organizations (PROs) plays a significant role in enhancing the quality of patents and their commercialization potential. Pilot collaboration initiatives serve as practical examples of successful university-industry partnerships in priority fields. For example, projects in renewable energy, digital transformation, or healthcare can serve as test cases to refine methodologies and demonstrate the potential of university-business cooperation.

6. Recommendations and Future Directions

Cross-disciplinary training programs equip researchers and business students with essential skills in intellectual property management, commercialization strategies, and market analysis, fostering a collaborative innovation ecosystem. Additionally, key performance indicators such as the number of joint R&D projects, conversion rates of academic research outputs into market-ready products, and licensing revenues offer valuable metrics for evaluating TTO operations.

Feedback mechanisms are essential for ensuring continuous improvement. Digital tools such as the European Patent Office's (EPO) Deep Tech Finder provide opportunities for Bulgarian universities to identify potential international collaborators, including startups, investors, and industry leaders. Regular feedback sessions with industry partners also allow universities to adapt their strategies and focus areas in response to evolving market demands.

Addressing systemic inefficiencies while capitalizing on emerging opportunities is critical for Bulgarian universities to thrive within the global innovation ecosystem. Despite the availability of robust frameworks, the practical implementation of technology transfer activities in Bulgaria remains insufficient, presenting both challenges and opportunities for improvement.

A primary obstacle facing Bulgarian TTOs is the fragmented relationship between academia and industry. Limited co-ownership of intellectual property, such as patents and utility models, reflects an absence of trust and alignment between the two spheres. Academic research outputs frequently fail to meet market-specific needs, and businesses are rarely engaged in the early stages of research and development (R&D). This disconnect is exacerbated by disparities in infrastructure and expertise among universities, particularly smaller institutions, which lack the resources to participate in complex commercialization processes.

Another significant challenge lies in the underutilization of existing institutional strategies. Although Bulgaria has adopted national frameworks for fostering innovation and technology transfer, these strategies often remain theoretical, with limited actionable outcomes. The absence of operational plans, measurable performance indicators, and effective monitoring systems has hindered TTOs from achieving tan-

gible results. These inefficiencies underscore the need for targeted interventions to bridge the gap between strategic intent and practical implementation.

Nevertheless, Bulgarian TTOs are well-positioned to leverage opportunities aligned with both national priorities and global best practices. The European Union's support mechanisms, including Horizon Europe and the European Institute of Innovation and Technology (EIT), offer substantial resources for fostering innovation and international collaboration. Participation in cross-border initiatives provides not only funding opportunities but also exposure to advanced technology transfer models.

Sectoral specialization represents a critical pathway for enhancing the impact of TTOs. The National Innovation Strategy for Smart Specialization (2021–2027) identifies key areas such as green energy, digital transformation, and healthcare as priority sectors for Bulgaria's economic and societal development. By aligning their activities with these priorities, TTOs can ensure that academic research outputs address pressing challenges. Additionally, the creation of regional innovation clusters through partnerships with businesses, governments, and research institutes can foster synergies between academia and industry while promoting economic growth in underdeveloped regions.

The development of human capital within TTOs is essential for optimizing technology transfer processes. Training programs focused on intellectual property management, licensing negotiations, and entrepreneurship equip TTO staff to navigate the complexities of commercialization. The exchange of personnel between universities and businesses can further facilitate mutual understanding and foster a collaborative innovation ecosystem. Complementary to this, public-private partnerships (PPPs) incentivize businesses to engage with universities, accelerating the commercialization of academic innovations.

Digital transformation also plays a pivotal role in enhancing the visibility and outreach of Bulgarian universities. Advanced tools, such as the European Patent Office's Deep Tech Finder, enable universities to connect with global investors, startups, and research organizations, expanding their innovation networks. These platforms also provide businesses with direct access to academic capabilities, fostering international collaboration and facilitating the identification of tailored R&D solutions.

To address systemic challenges, Bulgarian universities must focus on operationalizing existing frameworks, prioritizing practical collaboration initiatives, and incentivizing effective commercialization. Transforming theoretical strategies into actionable plans requires the establishment of clear timelines, accountability measures, and performance metrics. Pilot projects in priority sectors, such as green energy and digital technologies, can serve as proof-of-concept models, demonstrating the potential of university-business partnerships and building trust among stakeholders. Additionally, introducing financial incentives for universities that achieve measurable commercialization outcomes motivates research teams to prioritize projects with real-world impact.

By integrating these targeted measures with the outlined comprehensive meth-

odology, Bulgarian TTOs can significantly enhance their operational efficiency and strategic impact. Addressing inefficiencies, fostering sectoral specialization, and leveraging digital transformation will position Bulgarian universities as pivotal contributors to the global innovation landscape. Through sustained efforts and alignment with national and international priorities, TTOs can bridge the gap between academic research and societal needs, driving transformative innovation and economic growth.

As the Fourth Industrial Revolution accelerates, artificial intelligence (AI) emerges as a transformative force capable of redefining traditional TTO practices. Integrating AI tools into the methodologies discussed above presents unparalleled opportunities for optimizing operations and maximizing impact.

As we navigate the era of the Fourth Industrial Revolution, characterized by rapid advancements in artificial intelligence (AI), automation, and digital transformation, TTOs face an unprecedented opportunity to harness these technologies for optimizing their operations and amplifying their impact. AI tools offer immense potential to revolutionize traditional TTO processes, ensuring they remain agile and effective in this dynamic environment. By leveraging AI-driven platforms, TTOs can enhance technology scouting by analysing extensive datasets and identifying research outputs with the highest commercialization potential. These tools can automate market-readiness assessments and technical feasibility evaluations, significantly reducing the time and resources required. Moreover, predictive analytics powered by AI can anticipate industry trends, enabling TTOs to align academic research with emerging market demands.

In the realm of intellectual property (IP) management, AI-powered tools like natural language processing (NLP) can streamline patent searches, detect prior art, and assist in drafting precise IP documentation. Machine learning algorithms can facilitate better matchmaking between university innovations and industry partners by analysing compatibility, past collaborations, and sector-specific needs. Recommendation systems further enable personalized engagement, suggesting tailored licensing opportunities and partnerships. Additionally, AI-powered digital platforms, such as the European Patent Office's (EPO) Deep Tech Finder, can enhance TTOs' ability to connect with global investors, startups, and industrial collaborators, creating new avenues for innovation.

For Bulgarian universities, embracing AI tools is not merely an option but a strategic necessity. The global shift towards AI-enabled systems demands that TTOs position themselves as leaders in innovation ecosystems. Failure to integrate these advanced technologies risks falling behind in a rapidly evolving landscape.

By adopting AI, TTOs can improve decision-making, streamline operational efficiency, and maximize the commercialization of academic research. In doing so, they not only address the immediate needs of the Fourth Industrial Revolution but also prepare for future challenges, securing their role as critical drivers of innovation and economic development.

Conclusion

As Albert Einstein aptly stated, "The measure of intelligence is the ability to change". This insight captures the essence of adaptability, a critical quality for institutions navigating the complexities of an ever-evolving global landscape. Bulgarian universities and their Technology Transfer Offices (TTOs) must embrace this principle, positioning themselves as agile and forward-thinking contributors to societal progress and economic development.

The strategies and methodologies outlined in this article emphasize the importance of collaboration, innovation, and resilience. By leveraging interdisciplinary approaches, fostering partnerships with industry, and aligning with national and international priorities, Bulgarian universities can overcome systemic challenges and transform their role within the innovation ecosystem. Sustainability lies in their ability to innovate amidst uncertainty, addressing critical global challenges such as climate change, resource scarcity, and shifting economic paradigms.

Furthermore, the advent of the Fourth Industrial Revolution underscores the urgency of adaptability. While artificial intelligence (AI) offers transformative potential for TTO operations, its broader implication is a call to embrace change as a fundamental driver of progress. Universities that integrate advanced technologies and prioritize practical implementation will not only thrive during times of stability but will also remain resilient in periods of crisis, ensuring they continue to contribute meaningfully to societal advancement.

In conclusion, the vision for Bulgarian universities is clear: to evolve as centres of transformative innovation, addressing the demands of a rapidly changing world. By building on the methodologies and recommendations provided in the present article and by embracing a culture of adaptability, they can achieve sustainable growth, advance the frontiers of knowledge, and solidify their place as vital contributors to national, regional, and global progress.

REFERENCES

MCCOWAN, T., 2020. The impact of universities on climate change: a theoretical framework. *Centre for Global Higher Education, working paper,* no. 55, Published by the Centre for Global Higher Education, Department of Education, University of Oxford, ISSN 2398-564X.

PARTEKA, A.; PŁATKOWSKI, P.; SZYMCZAK, S. & WOLSZCZAK-DERLACZ, J., 2024. A dataset on knowledge creation and patenting by European Higher Education Institution*s* (KC-HEI). *GUT FME Working Paper Series A,* No. 2 (73), Gdansk University of Technology, Faculty of Management and Economics, Gdansk. https://hdl.handle.net/10419/300341.

THALES MEDIA, 15-3-2024, Press release, *Post-quantum cryptography: six French cyber players join forces to design the secure communication networks of tomorrow,* https://www.thalesgroup.com/en/worldwide/security/press_release/post-quantum-cryptography-six-french-cyber-players-join-forces.

Websites

2023 Annual Report Karlsruhe Institute of Technology Report https://www.kit.edu/downloads/jahresbericht_2023_en.pdf

2024 Statistics and indicators, European Patent Office, January 29, 2024 https://www.epo.org/en/about-us/statistics/patent-index-2023/statistics-and-indicators/applicants/categories

Karlsruhe Institute of Technology, "Research to Business" online platform https://www.techtransfer.kit.edu/english/index.php

Karlsruhe Institute of Technology, Sustainability Strategy, 15 April 2024 https://www.kit.edu/downloads/KIT-Sustainability-Strategy.pdf

National Innovation Strategy for Smart Specialization 2021–2027, Ministry of Innovation and Growth of Republic of Bulgaria, adopted with Decision No. 1015 of the Council of Ministers on December 15, 2022, https://www.mig.government.bg/wp-content/uploads/2022/12/isis-2021-2027.pdf

World Intellectual Property Organization (WIPO): IP Statistics Data Center https://www3.wipo.int/ipstats/key-search/indicator

www.bpo.bg

https://www.techtransfer.kit.edu/english/index.php

✉ **Dr. Ralitsa Zayakova-Krushkova, Assist. Prof.**
FDIBA – Faculty of German Engineering and Industrial Management Education
Technical University – Sofia
Studentski district
11, Prof. Georgi Bradistilov St.
1756 Sofia, Bulgaria
E-mail: rzayakova@tu-sofia.bg

✉ **Dr. Eng. Alexander Mitov, Assoc. Prof.**
ORCID ID:0000-0002-5942-9165
Hydroaerodynamics and Hydraulic Machines Department
Technical University – Sofia
Studentski district
11, Prof. Georgi Bradistilov St.
1756 Sofia, Bulgaria
E-mail: a_mitov@tu-sofia.bg