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19th International Technology Transfer Conference

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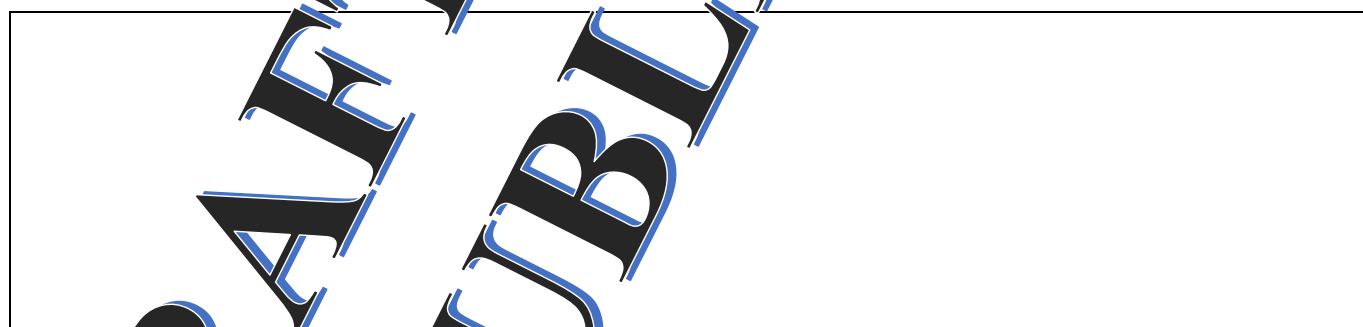
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PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2026

29. mednarodna multikonferenca *Informacijska družba* se odvija v času izjemne rasti umetne inteligence, njenih aplikacij in vplivov na človeštvo. Vsako leto bolj vstopamo v novo dobo, v kateri generativna umetna inteligenca ter drugi inovativni pristopi oblikujejo poti k superinteligenci in singularnosti, ki bosta krojili prihodnost človeške civilizacije. Naša konferenca je tako hkrati tradicionalna znanstvena in akademsko odprta, pa tudi inkubator novih, pogumnih idej in pogledov.

Letošnja konferenca poleg umetne inteligence vključuje tudi razprave o perečih temah današnjega časa: ohranjanje okolja, demografski izzivi, zdravstvo in preobrazba družbenih struktur. Razvoj UI ponuja rešitve za številne sodobne izzive, kar poudarja pomen sodelovanja med raziskovalci, strokovnjaki in odločevalci pri oblikovanju trajnostnih strategij. Zavedamo se, da živimo v obdobju velikih sprememb, ko je ključno, da z inovativnimi pristopi in poglobljenim znanjem ustvarimo informacijsko družbo, ki bo varna, vključujoča in trajnostna.

V okviru multikonference smo letos združili dvanajst vsebinsko raznolikih srečanj, ki odražajo širino in globino informacijskih ved: od umetne inteligence v zdravstvu, demografskih in družinskih analiz, digitalne preobrazbe zdravstvene nege ter digitalne vključenosti v informacijski družbi, do raziskav na področju kognitivne znanosti, zdrave dolgoživosti ter vzgoje in izobraževanja v informacijski družbi. Pridružujejo se konference o legendah računalništva in informatike, prenosu tehnologij, mitih in resnicah o varovanju okolja, odkrivanju znanja in podatkovnih skladiščih ter seveda Slovenska konferenca o umetni inteligenci.

Poleg referatov bodo okrogle mize in delavnice omogočile poglobljeno izmenjavo mnenj, ki bo pomembno prispevala k oblikovanju prihodnje informacijske družbe. »Legende računalništva in informatike« predstavljajo domači »Hall of Fame« za izjemne posameznike s tega področja. Še naprej bomo spodbujali raziskovanje in razvoj, odličnost in sodelovanje; razširjeni referati bodo objavljeni v reviji *Informatica*, s podporo dolgoletne tradicije in v sodelovanju z akademskimi institucijami ter strokovnimi združenji, kot so ACM Slovenija, SLAIS, Slovensko društvo Informatika in Inženirska akademija Slovenije.

Vsako leto izberemo najbolj izstopajoče dosežke. Letos je nagrado *Michie-Turing* za izjemen življenjski prispevek k razvoju in promociji informacijske družbe prejel **Denis Trček**, priznanje za raziskovalni dosežek leta pa **Jure Leskovec**. »Informacijsko limono« za najmanj primerno informacijsko storitev je prejel informacijski sistem za dolgotrajno oskrbo. »Informacijsko jagodo« za najboljši sistem ali storitev v letih 2025/2026 pa je prejela elektronska osebna izkaznica. Iskrene čestitke vsem nagrajencem!

Naša vizija ostaja jasna: prepoznati, izkoristiti in oblikovati priložnosti, ki jih prinaša digitalna preobrazba, ter ustvariti informacijsko družbo, ki koristi vsem njenim članom. Vsem sodelujočim se zahvaljujemo za njihov prispevek — veseli nas, da bomo skupaj oblikovali dosežke, ki bodo krojili usodo Slovenije in sveta.

Mojca Ciglarič, predsednica programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD TO THE MULTICONFERENCE INFORMATION SOCIETY 2026

The 29th International Multiconference *Information Society* takes place at a time of remarkable growth in artificial intelligence, its applications, and its impact on humanity. Each year we move further into a new era in which generative artificial intelligence and other innovative approaches are opening paths toward superintelligence and the singularity — two developments that will shape the future of human civilization. Our conference is at once a traditional scientific meeting, an academically open forum, and an incubator of new and bold ideas.

In addition to artificial intelligence, this year's conference also addresses pressing issues of our time: environmental protection, demographic challenges, healthcare, and the transformation of social structures. The development of AI offers solutions to many contemporary challenges and underscores the need for collaboration among researchers, professionals, and policymakers in shaping sustainable strategies. We are aware that we live in a period of profound change, when innovative approaches and deep knowledge are essential if we are to build an information society that is safe, inclusive, and sustainable.

This year's multiconference brings together twelve thematically diverse meetings that reflect the breadth and depth of the information sciences. They range from artificial intelligence in healthcare, demographic and family studies, the digital transformation of nursing, and digital inclusion in the information society, to research in cognitive science, healthy longevity, and education in the information society. They are joined by conferences on the Legends of Computing and Informatics, technology transfer, myths and truths of environmental protection, knowledge discovery and data warehouses, and, of course, the Slovenian Conference on Artificial Intelligence.

Alongside the papers, round tables and workshops will enable an in-depth exchange of views that will contribute substantially to shaping the future information society. *Legends of Computing and Informatics* serves as a national Hall of Fame for outstanding individuals in the field. We will continue to foster research and development, excellence, and collaboration. Extended papers will be published in the journal *Informatica*, building on a long-standing tradition and on cooperation with academic institutions and professional associations, including ACM Slovenia, SLAIS, the Slovenian Society Informatika, and the Slovenian Academy of Engineering.

Each year we single out the most distinctive achievements. This year the *Michie–Turing Award* for an outstanding lifetime contribution to the development and promotion of the information society was presented to **Denis Trček**, and the Award for Research Achievement of the Year to **Jure Leskovec**. The “Information Lemon” for the least appropriate information service went to the long-term care information system. The “Information Strawberry” for the best system or service in 2025/2026 went to the electronic identity card. Our warmest congratulations to all the award winners.

Our vision remains clear: to recognize, use, and shape the opportunities of digital transformation, and to create an information society that benefits all of its members. We thank all participants for their contributions. We look forward to shaping, together, achievements that will determine the fate of Slovenia and of the world.

Mojca Ciglarič, Chair of the Program Committee
Matjaž Gams, Chair of the Organizing Committee

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Duško Jodić

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October 2026 / 7 October 2026
Novo mesto, Slovenia

FOREWORD

Dear guests, experts, panellists, and participants,
Welcome to the 19th International Technology Transfer Conference!

This year, the Conference takes place in the historic city of Novo mesto and is hosted by the Faculty of Information Studies and the Rudolfovo Science and Technology Centre Novo mesto. Following last year's Conference in Koper, we continue the practice of bringing the Conference to different regions of Slovenia, increasing the visibility of knowledge transfer activities and strengthening cooperation with regional research institutions, innovation actors, and local industry.

Since its inception, the Jožef Stefan Institute has served as the initiator and main organiser of the Conference. This year, we are pleased to organise the event together with 13 participating research and higher education institutions representing Slovenia's two national consortia of Knowledge Transfer Offices (KTOs). For the third consecutive year since their establishment in 2024, the Conference serves as their joint annual event.

Over these three years, cooperation among KTOs has continued to develop through joint initiatives, professional networking, awareness-raising, and the exchange of experience and good practices. Increasingly, this cooperation also reaches beyond the KTO community, connecting it with the wider Slovenian and international innovation ecosystem, including the Slovenian Intellectual Property Office (SIPO), the Ministry of Education, Science and Youth and other ministries, the Slovenian Research and Innovation Agency (ARIS), companies, innovation support organisations, the World Intellectual Property Organization (WIPO), and other partners.

These growing connections are also reflected in new national instruments supporting research and innovation. Together with other stakeholders in the Slovenian research, development, and innovation ecosystem, KTOs contributed to the development of the ARIS RDI Hub, launched in June 2026 as a national digital platform bringing together information on funding opportunities, support services, stakeholders, and events, and connecting science, industry, innovation support organisations, and policy.

In parallel, the KTO community continues to provide information and support to companies through the established Knowledge Transfer Slovenia (KTS) national platform – Prenos znanja Slovenija, providing a single digital entry point to research expertise, innovations, technologies, and collaboration opportunities. The platform connects Knowledge Transfer Offices across Slovenian universities, public research institutes, and other research and higher education institutions, making the national knowledge transfer network more visible and accessible to industry.

The themes addressed by ITTC in recent years reflect the gradual development of this ecosystem. Discussions have progressed from the principles and practices of knowledge valorisation, through institutional self-evaluation and stronger support for research commercialisation and spin-outs, towards an increasingly important question: how can the established structures, expertise, and support mechanisms enable more effective co-creation between research and industry?

This is at the heart of this year's Conference theme, "Strengthening Industry-Academia Co-creation for More Efficient Knowledge Valorization." The focus represents a natural next step: moving from strengthening the knowledge transfer system itself towards making its connections with industry more effective and translating research knowledge into economic and societal value.

The programme reflects this ambition by bringing together perspectives from research, knowledge transfer, innovation policy and funding, industry, and the business community. We are especially pleased to welcome Dr Paul Maguire, Head of Innovation and Knowledge Transfer at Technological University Dublin, and Mr Aleš Brenčič, Director of Production Process at Renault Group Revoz, Novo mesto, as keynote speakers. They will also join the round table on this year's Conference theme together with Mito Žnidarko from the Slovenian Research and Innovation Agency (ARIS) and Nina Šab from the Chamber of Commerce of Dolenjska and Bela krajina. The discussion will consider how closer interaction between research organisations, higher education institutions, companies, public institutions, and innovation-support actors can lead to more effective co-creation and knowledge valorisation.

An important part of this process remains the direct support of research teams in bringing promising results closer to application. More than one hundred entrepreneurial research teams have participated in ITTC innovation competitions over the years, with some subsequently developing successful spin-out companies. This year, the Conference Prize for the Best Innovation 2026 continues this tradition by recognising technologies from participating research and higher education institutions with potential for further commercialisation and valorisation.

The WIPO Awards complement these activities by recognising the role of intellectual property, inventors, and enterprises in transforming research results into innovation and strengthening links between research and industry.

Alongside its professional and policy-oriented programme, the Conference continues to provide a forum for peer-reviewed research on knowledge and technology transfer. For the seventh consecutive year, scientific contributions form part of the programme, connecting research evidence with the practical challenges faced by knowledge transfer professionals and innovation stakeholders.

We extend our sincere gratitude to our hosts, the Faculty of Information Studies and the Rudolfovo Science and Technology Centre Novo mesto, and to all co-organisers, Knowledge Transfer Offices, speakers, reviewers, authors, and participants who contribute to the Conference.

We would also like to express our sincere appreciation to the Ministry of Education, Science and Youth for its long-standing support of the International Technology Transfer Conference and knowledge transfer activities in Slovenia. Our special thanks go to the Ministry for co-financing this year's Conference as part of the Science Month campaign and through the Public Call for Supporting the Activities of Knowledge Transfer Offices, co-financed by the Republic of Slovenia and the European Union through the European Regional Development Fund (ERDF). We warmly thank the EIT RawMaterials Slovenia Representative, SPIRIT Slovenia and Jožef Stefan Institute for their financial support of the pitch session.

Dear guests, we hope that the 19th ITTC will not only continue the dialogue developed over previous years, but also create new connections and concrete opportunities for cooperation between research, higher education, industry, and the wider innovation ecosystem.

May this Conference help us turn connections into collaboration, and knowledge into impact.

Thank you for being part of this journey, and we look forward to an inspiring exchange of ideas in Novo mesto.

Programme Committee of the 19ITTC

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Bridging Research and Industry: Technology Transfer of an AI-Based Autonomous Quality Control System for Small-Batch Manufacturing

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Abstract

Quality control is a major challenge in small-batch manufacturing, particularly when producing safety-critical metal components with strict dimensional tolerances. Conventional inspection approaches, including coordinate measuring machines (CMM) and manual 3D scanning, are often time-consuming, require highly skilled personnel, and limit the feasibility of 100% inspection. This paper presents a technology transfer case study describing the development and industrial deployment of an autonomous quality control system that combines artificial intelligence, robotics, and 3D scanning. The solution was jointly developed by the Rudolfovo Science and Technology Centre, CNC Borštnar Ltd., and 3D-ing Ltd. through a collaborative innovation process. The system autonomously generates scanning trajectories using reinforcement learning and performs dimensional inspection without prior programming or CAD-based path planning. The paper focuses on the technology transfer process, industrial validation, commercialisation potential, and lessons learned from transferring advanced AI research into a manufacturing environment.

Keywords

Technology transfer, artificial intelligence, quality control, robotics, 3D scanning, manufacturing innovation, SME.

1 Introduction

Artificial intelligence (AI), robotics, and advanced sensing technologies are transforming modern manufacturing by enabling higher productivity, flexibility, and product quality.

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These technologies form one of the key pillars of Industry 4.0 and are increasingly recognised as strategic drivers for strengthening the competitiveness of European manufacturing industries [1–3]. Despite significant advances in research, the transfer of AI-based manufacturing solutions from research laboratories to industrial practice remains limited, particularly among small and medium-sized enterprises (SMEs).

SMEs represent more than 99% of all enterprises in the European Union, employ approximately two-thirds of the European workforce, and generate over half of the EU's added value [1,2]. Unlike large manufacturers operating high-volume production lines, SMEs typically manufacture small batches with high product variability, short production runs, and frequent product changes. These characteristics make the deployment of conventional automation technologies significantly more challenging.

Quality control represents one of the most demanding production activities in such environments. Traditional coordinate measuring machines (CMMs) provide high measurement accuracy but require dedicated fixtures, extensive programming, and long setup times for every new product. Consequently, many SMEs perform only sample-based inspection, increasing the risk of undetected defects, product recalls, and unnecessary production costs [3].

The introduction of non-contact optical metrology, particularly structured-light 3D scanning, has significantly improved dimensional inspection by enabling rapid acquisition of complete surface geometries instead of individual measurement points [4]. Modern industrial scanners produce dense point clouds that support dimensional verification, geometric tolerancing, reverse engineering, and digital twin generation [4]. Nevertheless, data acquisition remains highly dependent on expert operators who determine scanner positioning, movement, and coverage quality. Existing robotic scanning systems typically require CAD models, predefined trajectories, or extensive offline programming before inspection can begin [5].

Recent advances in artificial intelligence have opened new possibilities for autonomous inspection planning. Reinforcement learning approaches such as Scan-RL [6] and GenNBV [7] demonstrated that AI agents can autonomously determine next-best viewpoints for unknown objects. Similarly, foundation models such as TRELLIS [8] and Foundation Pose [9] have significantly improved object initialisation and pose estimation from limited visual input. However, these approaches generally address only individual components of the inspection pipeline and rarely consider the practical constraints of industrial robotic systems, including robot kinematics, collision avoidance, limited scanning time, and integration into production environments.

Consequently, a considerable technology gap remains between academic research and industrial deployment. Although many AI algorithms demonstrate excellent performance under laboratory conditions, relatively few have been successfully transferred into operational manufacturing systems, particularly within SMEs. Bridging this gap requires not only technological innovation but also effective mechanisms for knowledge transfer, industrial validation, and collaboration between research organisations and manufacturing companies [10,11].

To address this challenge, the Rudolfovo Science and Technology Centre, in collaboration with CNC Borštnar Ltd. and 3D-ing Ltd., developed an autonomous AI-driven robotic inspection system capable of performing fully automated dimensional quality control without prior programming of inspection trajectories. The development and industrial validation of the system were carried out within the SRC EDIH 2.0 (European Digital Innovation Hub) project, which aims to accelerate the digital transformation of SMEs. The project represents a practical example of successful technology transfer, transforming research results in artificial intelligence, robotics, and 3D sensing into an industrial solution. The objective of this paper is to present and analyse this case study of technology transfer from research to industrial practice. In particular, the paper examines the main stages of the technology transfer process, from the identification of industrial needs and prototype development to industrial validation and preparation for commercialisation and identifies the key factors that contributed to the successful transfer of the developed technology into an operational SME manufacturing environment.

2 Research Background and Technology Development

The developed system integrates several advanced technologies: industrial robotics, structured-light 3D scanning, computer vision, generative AI models, and reinforcement learning algorithms. The inspection process begins with placing a component on a rotating platform. A camera mounted on a robotic arm captures initial images of the object. Based on these images, an AI model generates a simplified 3D representation of the part. This model serves as input for a reinforcement learning algorithm that autonomously determines an optimal scanning trajectory.

Unlike conventional systems that require predefined CAD-based paths, the proposed approach dynamically adapts to different

geometries without prior programming. The resulting scan data are processed and compared against the original CAD model, producing an automated inspection report and quality assessment. The system architecture was designed to be modular, enabling adaptation to different product sizes, scanner accuracies, and production environments.

3 Technology Transfer Process

The project represents a practical example of technology transfer from research to industry. Rudolfovo contributed expertise in artificial intelligence, machine learning, data processing, and algorithm development. CNC Borštnar Ltd. provided an industrial test environment, manufacturing expertise, and real-world quality control requirements. The additional industrial partner, 3D-ing Ltd., contributed specialised knowledge in 3D scanning technologies and system integration (Figure 1).

Several factors contributed to the successful technology transfer in this case. First, the project addressed a clearly defined industrial challenge at a time when Rudolfovo was already developing relevant expertise. Second, the collaboration brought together complementary expertise from the manufacturing company, the research organisation, and a specialised provider of 3D scanning technology. Third, different technological components were integrated into a complete solution specifically tailored to the industrial partner's production requirements.



Figure 1: Autonomous system for quality control. Photo: Rudolfovo

The technology transfer process followed several stages:

3.1 Stage 1: Industrial Problem Identification

The technology transfer process started with the identification of a concrete industrial challenge at CNC Borštnar Ltd., a Slovenian SME specialising in the production of high-precision metal components. The company faced significant limitations in its existing quality control procedures, including lengthy preparation times for coordinate measuring machines (CMMs), reliance on external 3D measurement providers, high inspection costs, and the inability to perform 100% inspection of small production batches economically. These challenges directly affected production efficiency, flexibility, and competitiveness. Through the SRC EDIH 2.0 project, the company was able to

express its technological needs and engage with a research organisation capable of developing an advanced digital solution tailored to its production environment.

3.2 Stage 2: Research and Prototype Development

Following the identification of industrial requirements, a multidisciplinary team consisting of researchers from Rudolfovo and industrial experts from 3D-ing Ltd. and CNC Borštnar Ltd. jointly defined the system requirements and technical specifications. The development phase focused on translating industrial needs into an autonomous inspection system by integrating artificial intelligence, reinforcement learning, computer vision, robotics, and structured-light 3D scanning. Several prototype iterations were developed, allowing continuous refinement of the AI algorithms for autonomous trajectory planning, object localisation, and adaptive scanning. The close interaction between researchers and end users ensured that the proposed solution addressed both technological challenges and practical manufacturing constraints (Figure 2).

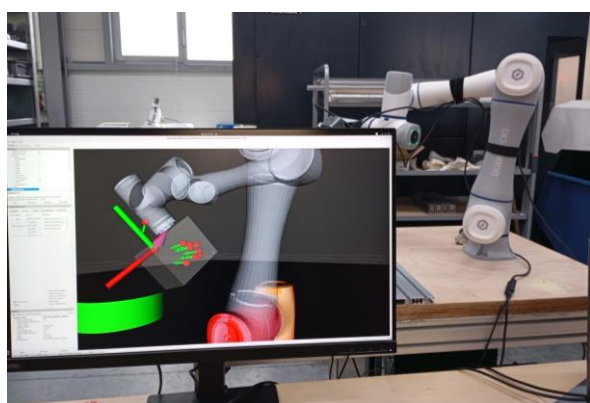


Figure 2: Autonomous system for quality control – developing different ideas. Photo: Rudolfovo

3.3 Stage 3: Industrial Validation

The developed prototype was deployed and validated directly in the operational manufacturing environment of CNC Borštnar Ltd. as part of the SRC EDIH 2.0 Test Before Invest (TBI) service. Validation included inspection of multiple workpieces with varying dimensions and geometric complexity under real production conditions. Performance indicators such as inspection time, scanning coverage, repeatability, and usability were continuously monitored. Engineers and machine operators actively participated in the evaluation process by providing practical feedback regarding workflow integration, ease of operation, and system robustness. This iterative validation process enabled continuous improvements to both the software and hardware components while simultaneously increasing user confidence in the new technology.

3.4 Stage 4: Commercialisation Preparation

Following successful industrial validation, the project has entered the commercialisation preparation phase. The

technology readiness level was assessed using the European Commission's TRL framework. The system was classified as TRL 8 based on the integration of the complete hardware and software solution, along with its testing and qualification under operational manufacturing conditions at CNC Borštnar Ltd. The validation involved inspecting multiple workpieces with varying dimensions and geometric complexity. The system was operated in the intended industrial environment, while relevant performance indicators, including inspection time, scanning coverage, repeatability, and usability, were evaluated. On this basis, the complete system was considered demonstrated and qualified for its intended application, supporting its classification at TRL 8. Intellectual property protection has been initiated through the Slovenian patent application No. P-202600074, filed with the Slovenian Intellectual Property Office (URSIL), covering the core technological innovations. Within the 12-month priority period, we intend to extend the protection by filing either an international PCT application or a European patent (EP) application. The preferred filing route and geographical scope of protection are still under consideration.

Potential application areas include precision metal manufacturing, automotive suppliers, aerospace production, toolmaking, and other industries requiring high-accuracy dimensional inspection. The experience gained during the project also provides a replicable methodology for transferring AI-based manufacturing technologies from research organisations to SMEs through European Digital Innovation Hubs, supporting the wider digital transformation of European industry.

4 Industrial Impact and Commercial Potential

The implementation of the proposed autonomous quality control system has generated significant technical, economic, and organisational benefits for the industrial partner. By integrating artificial intelligence, robotics, and automated 3D inspection into the existing production workflow, the company has substantially improved the efficiency and reliability of its quality assurance process.

One of the most important outcomes is the considerable reduction in manual inspection activities. The autonomous system minimises the need for highly skilled operators and eliminates the dependence on external providers of specialised 3D measurement services. At the same time, the transition from sample-based inspection to full inspection of every manufactured component significantly increases process reliability and reduces the risk of undetected defects reaching customers. The implementation also contributes to lower material consumption through the early detection of production errors, reducing rework, scrap, and unnecessary production costs. Furthermore, the increased consistency and repeatability of the inspection process strengthen customer confidence and improve the company's overall quality management system.

Based on the pilot implementation at CNC Borštnar Ltd., the estimated annual economic impact exceeds €100,000, resulting from reduced labour costs, lower expenditure on external measurement services, fewer customer complaints, decreased material waste, and shorter production lead times. Although the current implementation has been validated in a single industrial

environment, the developed solution demonstrates strong scalability and can be adapted to different production systems with only minor modifications. Rudolfovo is the sole owner of the patent application and the associated intellectual property rights; therefore, no joint ownership of the protected results is envisaged among the project partners. Several commercialisation routes are currently being considered, including licensing the technology to interested industrial partners, assigning or selling the patent rights, or establishing a researcher-led spin-out company that would commercialise the technology under an appropriate agreement with Rudolfovo. The final exploitation model has not yet been selected and will depend on the further development of the technology and discussions with potential commercial partners.

From a commercialisation perspective, the solution addresses a rapidly growing market for intelligent inspection and digital manufacturing technologies. Potential customers include companies operating in precision metal processing, automotive manufacturing, aerospace, toolmaking, medical device production, and other industries where dimensional accuracy and product traceability are critical. As European manufacturers continue investing in Industry 4.0 technologies, artificial intelligence, and digital quality assurance, the proposed system offers a practical and economically viable solution for SMEs seeking to modernise their production processes without requiring extensive programming or specialised metrology expertise.

The project also demonstrates the important role of European Digital Innovation Hubs (EDIHs) in accelerating technology adoption. Through the SRC EDIH 2.0 Test Before Invest service, the industrial partner was able to evaluate and validate the technology under real production conditions before making long-term investment decisions. This significantly reduced technological and financial risks while facilitating faster industrial deployment.

5 Conclusion

This paper presented a technology transfer case study that described the successful development and industrial validation of an autonomous, AI-based quality control system for small-batch manufacturing. The presented solution integrates artificial intelligence, robotics, computer vision, and 3D scanning into an integrated inspection workflow that autonomously plans scanning trajectories, acquires high-quality 3D data, and performs dimensional quality assessment without prior programming.

Beyond the technological innovation, the project demonstrates how close collaboration between a research organisation and an industrial SME can significantly accelerate the adoption of advanced digital technologies. Through the SRC EDIH 2.0 initiative, the developed solution was successfully transferred from research to a real manufacturing environment using the Test Before Invest approach, enabling the industrial partner to validate the technology before making a large-scale investment. This process reduced implementation risks while simultaneously increasing confidence in the practical applicability of AI-based manufacturing solutions.

The industrial validation confirmed the potential of autonomous quality control to improve production efficiency, reduce inspection costs, increase process flexibility, and enable the transition from sample-based to 100% quality inspection. The project also highlights the importance of interdisciplinary collaboration, continuous interaction with end users, and early consideration of commercialisation and intellectual property protection as key success factors for effective technology transfer. The presented methodology is not limited to dimensional inspection; it provides a transferable framework for deploying AI-enabled robotic systems in other industrial applications that require intelligent sensing, autonomous decision-making, and adaptive manufacturing processes. As European manufacturing continues its transition toward Industry 5.0, the experience gained within this project demonstrates how European Digital Innovation Hubs can serve as effective catalysts for connecting research excellence with industrial needs and accelerating the digital transformation of SMEs.

Future work will focus on extending the system with multimodal sensing technologies, integrating foundation AI models for more generalised object understanding, and validating the proposed framework across additional industrial sectors. These activities will further strengthen the technology's commercialisation potential and contribute to the wider adoption of intelligent, autonomous quality control systems across European manufacturing.

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Universities as Engines of Dual-Use Innovation: A Case Study of the MIT Model for Defense, Security and Resilience

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Abstract

Defense, security and resilience (DSR) is becoming a named category of capital allocation. JPMorgan Chase's \$1.5 trillion Security and Resiliency Initiative, the NATO Innovation Fund and dedicated venture practices signal that banks, allied governments and institutional investors now treat national and economic security as an investable field. Universities hold much of the research base this capital is looking for, yet the route from laboratory work to fielded capability is rarely described in institutional terms. This paper uses the Massachusetts Institute of Technology (MIT) as a descriptive case to examine how a research university organizes the translation of fundamental research into dual-use technologies. Drawing on a structured mapping of MIT laboratories, ventures and educational programs against current DSR investment frameworks, the paper identifies four interacting mechanisms: research pipelines connected to mission problems, venture formation with structured acceleration, strategic capital pathways, and the integration of technical, entrepreneurial and mission expertise. The case suggests that technology transfer for dual-use markets requires universities to act as intermediaries between laboratories, founders, investors and government users, and it offers lessons for institutions building comparable capacity.

Keywords

dual-use innovation, technology transfer, research universities, defense innovation, commercialization, innovation ecosystems

1 Introduction

In October 2025, JPMorgan Chase announced a \$1.5 trillion Security and Resiliency Initiative, organized around four themes and 27 sub-areas that range from advanced manufacturing and critical minerals to frontier technologies [1]. The announcement is the most visible sign of a wider shift. The NATO Innovation Fund, a venture fund backed by 24 allied nations, has published its own taxonomy of defense, security and resilience (DSR) investment [2]. Andreessen Horowitz runs a dedicated American Dynamism practice [3], a multilateral defense bank has been proposed [4], and pension funds and sovereign allocators have begun to revise policies that once excluded defense holdings [5]. A category that many institutional investors treated as stigmatized only a few years ago is being assembled into an investable field.

Universities sit upstream of much of the technology this capital is seeking. They train the people, produce the intellectual property and operate the shared facilities on which dual-use ventures depend. What is far less well documented is how a university actually organizes the movement of research from laboratory to deployed capability in markets where commercial and government adoption are intertwined. Accounts of academic technology transfer tend to concentrate on licensing activity and spin-out counts [12], while DSR markets add features that standard processes were not designed for, including government customers, procurement cycles and problem sets that are hard for founders to see from campus.

For the technology transfer community, this shift changes the job. Offices and intermediaries built around licensing to established industry now face investors who want venture-ready teams, government customers with their own adoption logic, and students who arrive expecting to found companies rather than join them. Universities also carry a wider obligation here. Preparing the next generation of researchers, innovators and entrepreneurs to work on strategically important problems in a

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strong and principled way is part of their mission, not a distraction from it.

This paper asks how research universities can structure ecosystems that translate fundamental research into dual-use technologies and real-world DSR capabilities. It examines MIT as a descriptive institutional case. The contribution is a synthesis of the case into four translation mechanisms and a set of implications for universities, technology transfer offices and innovation intermediaries that are building comparable capacity. The remainder of the paper describes the analytical approach, develops the MIT model, and draws out what other institutions can take from it.

2 Analytical approach

The analysis is a descriptive case study combined with a structured mapping exercise based on secondary evidence. MIT research groups, shared facilities, spin-out companies and educational programs were mapped against the 27 sub-areas of the JPMorgan initiative [1] and the technology taxonomy used by the NATO Innovation Fund [2]. Sources include public institutional records, investor reports and prior studies of MIT entrepreneurship [8].

The mapping follows the four themes of the JPMorgan framework: supply chain and advanced manufacturing, defense and aerospace, energy independence and resilience, and frontier and strategic technologies. Within each theme, the sub-areas run from critical minerals and shipbuilding to secure communication, battery storage and quantum computing. The mapping is a snapshot taken in 2025 from records current at that time, although several of the examples cited reach back further. A sub-area was counted as having an active MIT presence when at least one named faculty group, laboratory or center had a publicly documented research program addressing it. The exercise distinguishes between research activity, commercialization through venture-scale companies with MIT-affiliated founders, and deployment of technology at scale with federal partners. On these criteria, research activity was found in all 27 sub-areas, commercialization in most of them, and deployment at scale in a smaller subset. That breadth is what makes MIT a useful single case for studying how translation is organized, and it is evidence of presence rather than of performance.

Rather than reproducing that taxonomy, which exceeds the scope of a short paper, the analysis asks what recurs across it: which institutional structures appear again and again wherever research has moved into fielded capability. The approach is descriptive. It supports propositions about how translation is organized, not causal claims about institutional performance. Market figures quoted in DSR investment frameworks are model-derived projections that rest on mapping assumptions, and they are used here only as context for the scale of capital involved.

3 The MIT dual-use translation model

MIT has operated as a dual-use research institution since before the term existed. Radar work in the wartime Radiation Laboratory, decades of federally sponsored research, and the RSA cryptography that underpins modern digital security all moved between military and civilian application. The institute has also long taught to the mission side, from war gaming and

naval architecture programs for serving officers to courses that enroll active-duty personnel and reservists. What the case makes visible is not any single technology but the institutional pattern behind such examples. Four mechanisms recur, summarized in Table 1.

3.1 Research pipelines connected to mission problems

The first mechanism ties fundamental research agendas to mission-relevant problems early, rather than searching for applications after the fact. Federal programs in the DARPA tradition have long funded MIT laboratories such as CSAIL, the Research Laboratory of Electronics, MIT.nano and the MIT Energy Initiative, and Lincoln Laboratory gives the institute a standing interface with defense sponsors as a federally funded research and development center. Research questions are therefore shaped by operational needs while the work itself remains fundamental.

The mapping shows what this looks like across the four themes. In energy, work on high-field superconducting magnets at the Plasma Science and Fusion Center underpins compact fusion designs now being commercialized. In defense and aerospace, faculty research on autonomous systems has informed the technology stacks of ventures operating at scale. Gallium nitride semiconductor work feeds radar and satellite communication components, and a dedicated center carries the same pattern into quantum engineering. In each case the research stayed fundamental while its questions were framed with an operational end in mind. The volume of protectable output is considerable: MIT has ranked first among single-campus universities in US patents granted for ten consecutive years [7].

3.2 Venture formation and structured acceleration

A second mechanism turns research into companies able to carry it. MIT developed venture-building courses in fields such as climate, energy and health, and has since adapted the format to defense: current courses build dual-use ventures around problem sets provided by operational sponsors such as US Special Operations Command. The Technology Licensing Office connects the research community to industry and startups, and The Engine, an accelerator and venture organization built out of MIT for so-called tough tech, supplies space, equipment and patient capital [6]. Mission Innovation X (MIX) supports dual-use translation pathways directly and has published Dual-Use Readiness Levels, a framework that assesses a venture's maturity across technology, funding and customer readiness in commercial and government markets at the same time [11].

Practitioners associated with these programs argue that dual-use is a strategy a venture designs for, not a category it falls into [10]. Acceleration therefore has to be adapted rather than copied from commercial practice, consistent with earlier work showing that dual-use technology transfer takes several distinct forms and that the more ambitious of them require changes in how research and production are organized [13]. Many DSR problem sets are less visible to founders than commercial ones, so the courses import them directly from mission owners. Customer discovery runs through program offices and end users rather than open

markets, and founding teams have to learn procurement alongside product.

3.3 Strategic capital and funding pathways

Dual-use ventures face a funding gap between research grants and procurement revenue, and the MIT case shows a university helping to bridge it from both sides. Ventures are supported in using STTR and similar small-business research funding, and they are connected to venture capital whose theses align with DSR markets, alongside Engine-style patient capital for hardware-heavy companies [6].

The surrounding capital stack is now being assembled at scale. Bank commitments [1] join allied venture funds [2], dedicated investment practices [3] and proposed multilateral instruments [4], while pension funds and sovereign allocators watch closely and in a growing number of cases follow [5]. The stigma that kept many limited partners away from defense only a few years ago is easing. The lesson the case suggests for a university concerns proximity: where capital allocators sit close to the laboratories and ventures they fund, barriers to access appear to fall and development to move faster.

3.4 Integrating technical, entrepreneurial and mission expertise

The fourth mechanism is about people. Technology alone does not produce capability, and the MIT case shows deliberate effort to combine technical depth with managerial, entrepreneurial and mission experience. Educational programs bring serving officers, reservists and veterans onto campus, where they study alongside engineers and managers, and the institute's approach has been to make such individuals welcome and then integrate them into ventures rather than consulting operational experience at arm's length. Teams formed this way carry customer knowledge that purely technical founding groups lack. The alumni ecosystem is a large source of commercial and managerial depth: a 2015 study estimated that MIT alumni-founded companies employed 4.6 million people and generated nearly \$2 trillion in annual revenues [8], output that has been compared to the world's tenth largest economy [9].

3.5 Mechanism interaction and adoption as outcome

The mechanisms compound rather than operate in isolation. A venture formed in a course may build on laboratory research shaped by mission sponsors, license its intellectual property through the TLO, raise STTR and aligned venture funding, and recruit teammates with operational backgrounds from the same campus. Adoption by commercial and government customers is the outcome these four mechanisms produce together, not a fifth mechanism. The sequence of fundamental research, early-stage venture formation and then government procurement is a pattern that a wide range of universities, public and private, now take an interest in, and it runs in parallel with commercial sales rather than replacing them.

Spin-outs including Commonwealth Fusion Systems, VulcanForms, Form Energy and Shield AI now deliver systems to commercial and government customers, while research networks such as CSAIL, MITEI and MIT.nano continue to generate next-generation platforms that match federal and

private resilience goals. Commercial and national security outcomes are intertwined at this stage, which is why the preceding mechanisms have to treat both markets together from the start.

Table 1: Translation mechanisms in the MIT case and their technology-transfer function.

Mechanism	MIT case evidence	Transfer function
Mission-connected research pipelines	DARPA-tradition funding of CSAIL, RLE, MIT.nano, MITEI; Lincoln Laboratory	Shapes fundamental research around operational needs
Venture formation and acceleration	Venture-building courses with SOCOM problem sets; TLO; The Engine; Mlx readiness framework	Moves laboratory results into ventures fit for dual markets
Strategic capital pathways	STTR support; aligned venture capital; patient tough-tech capital	Bridges the gap between grants and procurement revenue
Integrated expertise	Officers, reservists and veterans on campus; alumni founder network	Combines technical, commercial and mission knowledge in teams

4 Implications for technology transfer

Generalizing from a single case calls for caution. MIT's history, scale and resources are not reproducible on demand, and the propositions below are lessons suggested by the case rather than tested laws.

The clearest lesson is that universities can act as innovation intermediaries rather than as licensors alone [14]. The value in the MIT case comes less from individual license deals than from standing structures that connect laboratories, founders, investors and mission users. Building those structures means giving outsiders a way in. Companies and capital allocators embedded alongside research groups gain access to pipeline technology, and future founders gain a place to learn.

Dual-use commercialization also demands parallel commercial and government adoption paths. Transfer processes designed for a single market underestimate the work of navigating procurement. Instruments that treat technology, funding and customer maturity together, such as the readiness levels developed at MIT [11], are a practical response, and technology transfer offices serving dual-use ventures will need similar adaptations of their own processes.

Capital and people deserve the same institutional attention as intellectual property. Funding pathways from research grants through STTR to aligned venture capital should be visible to ventures from the start, and mission expertise has to be recruited and integrated deliberately rather than assumed. Universities are well placed for both. Their convening power matters as much:

laboratories and academic brands can bring researchers, investors and mission stakeholders into one place, building the critical mass a young field needs.

5 Conclusion

The MIT case describes a university operating as a system for dual-use translation. Its central insight is that translation is organized rather than incidental: mission-connected research pipelines, venture formation, capital pathways and integrated expertise are linked by deliberate institutional structures, and their interaction is what turns research into capability. For technology transfer practice the case argues for treating dual-use commercialization as a distinct discipline with its own instruments, from adapted acceleration programs to readiness frameworks that span commercial and government markets. Other institutions cannot copy MIT's history, but the mechanisms are replicable in kind. As DSR capital allocation grows, universities that build such structures will be better placed to contribute research, ventures and people to the resilience of their societies.

6 Limitations and further research

This study is descriptive and rests on a single institution mapped through secondary sources. Much of that source base consists of institutional records, investor reports and accounts by practitioners connected to the programs described, including authors of this paper, so the analysis documents how the structures are organized rather than evaluating them independently. It does not benchmark MIT against other universities, measure the performance of the mechanisms it identifies, or establish causal links between institutional structures and venture outcomes. Market figures circulating in DSR frameworks are projections built on assumptions, and none of the argument here depends on them. Useful next steps include comparative case studies of universities building dual-use capacity, closer measurement of how ventures move between

commercial and government markets, and evaluation in practice of instruments such as dual-use readiness frameworks.

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Freedom to Operate in Early-Stage Research: A Research Governance Perspective

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Abstract

Freedom to Operate (FTO) analyses assess whether technologies can be commercialized without infringing third-party intellectual property rights, but are typically conducted late in the innovation process. This study examines current FTO practices in university technology transfer in Central and Eastern Europe and the potential value of earlier integration into publicly funded research. Semi-structured interviews with representatives of seven and structured survey of five TTOs across eight countries were analyzed thematically. Practices varied substantially, but respondents associated earlier IP assessment with improved research prioritization, identification of technological white spaces, commercialization readiness, and fewer costly redesigns. The study contributes empirical evidence from an under-researched regional context and proposes a staged governance model combining early patent intelligence with later formal FTO assessment.

Keywords

Freedom to Operate (FTO), Intellectual Property (IP) Management, Knowledge and Technology Transfer (KTT), Patent Intelligence, Research Governance, Technology Transfer Offices (TTOs), Research and Development (R&D).

1. Introduction

Universities are increasingly expected to generate economic and societal impact through research commercialization, making knowledge and technology transfer (KTT), including patenting, licensing, and spin-offs, a core function of modern research ecosystems.[1], [2]. At the same time, technological development is taking place in increasingly complex intellectual property (IP) environments, as reflected in the growing volume of patenting activity: the number of patent applications filed worldwide increased from 2,173,887 in 2013 to 3,385,204 in 2023, representing an increase of nearly 56% [3]. Particularly in biotechnology, pharmaceuticals, medical technologies, and semiconductors, innovation occurs within dense, overlapping

patent portfolios. [4]. As a result, organizations may discover only at advanced stages of development that critical aspects of their technology are covered by third-party IP rights, requiring costly redesign efforts, licensing negotiations, or, in some cases, abandonment of commercialization activities.

Recent research suggests that IP constraints may influence innovation trajectories much earlier than previously assumed. Studies on patent thickets and fragmented ownership structures indicate that restricted access to IP can shape the direction and intensity of subsequent innovation activities [4], [5]. Similarly, evidence from European patent opposition proceedings demonstrates that restoring Freedom to Operate can stimulate follow-on innovation and technological development [6]. These findings raise whether FTO considerations should be integrated earlier into research and development (R&D) processes.

Despite growing practical recommendations advocating earlier patent intelligence and IP landscape assessments, little empirical evidence exists regarding the extent to which research organizations incorporate FTO considerations into early-stage research activities, project selection, or research prioritization decisions. Existing literature primarily conceptualizes FTO as a commercialization tool, while its potential role as a research governance mechanism remains largely unexplored. Addressing this gap is relevant both scientifically and practically, as universities need to determine when IP intelligence can meaningfully inform research decisions without imposing costly formal FTO assessments prematurely.

This is particularly relevant for universities and publicly funded research, where commercialization pathways often emerge only after substantial R&D investment. Earlier identification of IP constraints may enable researchers to redirect efforts toward technological white spaces, pursue alternative design pathways, or establish licensing strategies before significant resources are committed. Against this background, this study addresses the empirical and practical gap by examining current FTO practices in Central and Eastern European technology transfer offices (TTOs) and assessing the potential of earlier FTO integration as a research-governance mechanism.

The study addresses three research questions (RQs): RQ1: At which stages and to what extent are FTO analyses conducted in university technology transfer? RQ2: What opportunities and barriers affect earlier FTO integration into publicly funded R&D? RQ3: How do technology transfer professionals perceive its contribution to research prioritization and commercialization readiness?

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2. Literature Review

2.1 FTO as a Commercialization and Risk Management Instrument

FTO refers to the assessment of whether a product, process, or technology can be developed, manufactured, or commercialized without infringing valid third-party IP rights [7]. Unlike patentability or novelty searches, which evaluate whether an invention itself may be protected, FTO focuses on infringement risks arising from existing patents held by others.

Traditionally, FTO has been regarded as a commercialization and market-entry tool used to support investment decisions, licensing negotiations, and litigation avoidance, particularly in patent-intensive sectors such as pharmaceuticals, biotechnology and medical devices [8]. Because patent rights are territorial and technology designs evolve over time, FTO is increasingly viewed as an iterative process rather than a single legal assessment [9]. Although legal and practitioner literature increasingly recommends conducting FTO assessments as early as possible in the innovation process, empirical studies continue to treat FTO primarily as a late-stage commercialization activity rather than a research planning instrument.

2.2 IP Constraints and Innovation Dynamics

Several streams of literature suggest that IP constraints influence innovation considerably earlier than the commercialization stages. Heller and Eisenberg [5] introduced the concept of the “anticommons”, arguing that fragmented ownership of IP rights may hinder downstream innovation by increasing transaction costs and limiting access to enabling technologies.

Similarly, the patent thicket literature describes how overlapping patent rights increase complexity and force firms to rely on cross-licensing, patent pools, and design-around strategies [4]. Hall and Ziedonis [10] demonstrated that firms in the semiconductor sector responded to such environments through strategic and defensive patenting behavior.

The most direct link between FTO and innovation outcomes was provided by Gaessler et al. [6], who found that restoring FTO through patent invalidation significantly increased follow-on innovation activity. Their findings demonstrate that FTO is not merely a legal issue but can directly influence innovation trajectories and the direction of technological development.

Parallel developments in technology management research increasingly recognize patent information as a strategic resource for competitor monitoring, technology forecasting, and R&D portfolio management [11]. Patent landscape studies have increasingly been recognized as tools for identifying technological opportunities, research gaps, and emerging trends. Van Rijn and Timmis [12] argue that academia and smaller innovators underutilize patent information but focus on patent landscapes rather than FTO or the timing of IP evaluations. Patent literature contains substantial technical knowledge that is only partially reflected in scientific publications. While the widely cited estimate that 80% of technical information is disclosed only in patents cannot be universally substantiated, Asche [13] confirms that patent literature is an essential complement to conventional literature reviews. It is further estimated that up to 30% of R&D expenditure is wasted through the redevelopment of existing inventions [14], [15], highlighting

the importance of systematic patent information searches during research and innovation activities.

2.3 Early-Stage FTO in Research: An Emerging Research Gap

Despite growing evidence that IP constraints influence innovation [16], little is known about how universities and public research organizations integrate FTO considerations into early-stage research activities. Existing studies of TTOs largely focus on patenting, licensing, and spin-off creation, while FTO receives comparatively little attention within the university technology transfer literature [17]. Compared with industrial R&D organizations, universities often operate with limited internal IP expertise and resources, making systematic early-stage FTO difficult to implement. Furthermore, researchers frequently perceive FTO as relevant only once a technology [6] approaches commercialization.

Consequently, existing literature provides little empirical evidence regarding whether early FTO practices exist, how frequently they are used, and whether they influence research prioritization or commercialization readiness. The potential role of FTO as a research governance mechanism capable of identifying technological white spaces, avoiding costly redesigns, and reducing sunk investments therefore remains largely unexplored.

This study addresses this gap by investigating current FTO practices among TTOs in Central and Eastern Europe and exploring perceptions regarding the opportunities and barriers associated with integrating FTO earlier into R&D processes.

3. Methodology

This study adopts an exploratory qualitative research design combined with a targeted survey to examine current FTO practices within university TTOs and explore perceptions of integrating FTO earlier into R&D. Given the limited empirical evidence on the timing and application of FTO in academic environments, a qualitative approach was selected initially to identify current practices, common themes, and propositions for future research. A targeted follow-up survey involving the same questions from the core questions of the interviews was conducted to validate the results.

Data were collected through purposive sampling to capture institutional diversity in size, technological focus, and maturity of technology transfer activities. Semi-structured interviews (seven) and targeted surveys (five) were conducted with representatives of 12 TTOs from eight European countries (Bosnia and Herzegovina, Croatia, Czechia, Estonia, Germany, Lithuania, Serbia, and Slovenia), including TTO directors, IP managers, patent specialists, and commercialization officers. Seven interviews were conducted online via Microsoft Teams between July and August 2026, recorded with participants' consent, and automatically transcribed using Microsoft Teams. In five cases, participants completed the same interview guide as a structured written questionnaire, providing an additional source for assessing whether themes identified in the interviews were consistent across participants.

The interview guide examined current FTO practices, the timing and triggers of FTO assessments, experiences with IP-

related commercialization barriers, and perceived opportunities and challenges associated with earlier FTO implementation. Data were analysed using thematic analysis following Braun and Clarke [18], [19] with QDA Miner Lite software. Coding focused on current FTO practices, initiation triggers, organizational barriers, and the perceived benefits of early-stage FTO. As an exploratory study, the findings provide analytical insights rather than statistical generalization and should be validated through larger-scale quantitative research. Participation was voluntary and all responses were anonymized for publication.

4. Results

The thematic analysis generated a set of codes that were grouped into four themes: (1) current institutional use and understanding of FTO; (2) conditions for early-stage FTO integration; (3) the strategic value of early IP assessment; and (4) an emerging governance model for FTO.

4.1 Current Institutional Use and Understanding of FTO

Current FTO practice varied considerably across the institutions, ranging from no distinct process to structured internal screening combined with external legal assessment. In several TTOs, FTO was not routinely integrated and patentability or prior state-of-the-art searches partly substituted for it. One respondent stated that *“Freedom to Operate is not, at present, a formally institutionalised step in our technology transfer process,”* noting that patentability and FTO were sometimes conflated despite addressing different questions.

Other institutions had introduced more structured procedures. One TTO described a *“hybrid model”* in which the internal team conducts preliminary FTO screening while full analyses for technologies approaching licensing, spin-off formation, or major investment are outsourced to patent counsel. Across the cases, timing, initiation, and delivery therefore remained heterogeneous, with FTO ranging from late, commercialization-driven assessment to earlier screening during invention assessment or proof of concept.

4.2 Conditions for Early-Stage Integration

The most recurrent barriers were limited TTO capacity, insufficient specialist expertise, lack of advanced search tools, and the cost and time required for external legal opinions. As one respondent summarized, *“In the majority of cases we skip a full FTO analysis due to resource constraints.”* These constraints were particularly evident in small TTOs, where a few staff members covered the entire technology transfer process. Researcher-related barriers included limited IP literacy, late engagement with TTOs, and academic incentives focused on publications, grants, and patents rather than commercialization. Nevertheless, experienced researchers and those with IP training were more likely to conduct early searches or proactively engage the TTO. Organizational factors such as decentralized structures, fragmented responsibilities, and procedures focused on disclosure or patent filing further hindered consistent FTO implementation. Respondents also argued that a full FTO

opinion is premature when technologies, claims, or target markets remain undefined. As one interviewee cautioned, *“I would really differentiate between application-driven and fundamental research... otherwise you might stifle the learning process.”* Enabling factors included validation funding, internal patent-information capacity, researcher training, national guidelines, EU project requirements, and funded access to patent databases and expertise.

4.3 Strategic value of early IP assessment

Despite differences in current practice, respondents broadly associated earlier IP assessment with improved research and commercialization decisions. The most frequently described contribution was the ability to identify blocking rights or crowded technological fields before substantial resources were committed. As one interviewee observed, *“The sooner you know about it, the sooner you can take countermeasures.”* This information could support project selection, redesign, design-around strategies, identification of exploitable niches, and redirection toward technological white spaces.

Respondents reported cases where third-party patents were discovered only after significant investment, while another case described early IP analysis enabled technology modification and subsequent protection. Early assessment was also linked to stronger patent claims, better choices between patents, know-how, and trade secrets, and fewer surprises during licensing, spin-out formation, and industry negotiations. As another respondent noted, *“Patent searches can reveal technological white spaces, inspire new research ideas, redirect projects toward patentable solutions, and provide valuable technical information that is often unavailable in scientific publications.”* However, respondents also emphasized that FTO does not replace market validation. As one interviewee stressed, *“It’s more important to do proper market validation and find out what is actually on the market and whether the market needs the innovation at all.”*

4.4 Emerging governance model for FTO

Across these practices, a staged and proportionate governance model emerged. Rather than commissioning comprehensive legal FTO at project outset, respondents supported early patent landscape or risk screening during project planning, invention assessment, or proof of concept. This was described as *“an initial mapping exercise rather than a comprehensive legal opinion.”*

More detailed assessment would follow as the technology and commercialization pathway become clearer, with formal external FTO reserved for licensing, spin-out formation, or market entry. The process may also require reassessment as the technology or competitive landscape develops; as one respondent noted, *“A follow-up or updated FTO opinion ... may still be conducted later, closer to licensing or spin-off formation.”* Within this model, the TTO primarily coordinates early patent intelligence, triages cases, and refers mature technologies for specialist legal assessment. Early IP intelligence thus functions as a research-governance tool, while formal FTO remains a later-stage commercialization instrument.

5. Discussion and Conclusion

The findings suggest that the key question is not whether FTO should be introduced earlier, but which level of IP assessment is appropriate at different stages of the research lifecycle. While literature primarily positions FTO as a commercialization and risk-management instrument [7], [9], the results indicate that universities increasingly distinguish between early patent intelligence supporting research decisions and formal legal FTO required before commercialization. This extends previous work on university KTT [1], [2], [17] by positioning early IP assessment as part of research governance rather than solely commercialization.

Regarding RQ1, no common institutional model emerged. Responsibility for FTO varied between researchers, TTOs, and external patent attorneys, reflecting institutional capacity rather than strategic design. Rather than acting as providers of comprehensive legal analyses, TTOs increasingly fulfil the coordinating role described by Weckowska [17], connecting researchers with IP expertise and supporting institutional decision-making. The findings therefore suggest that universities should formalize roles and responsibilities rather than prescribe a single timing for FTO.

Regarding RQ2, respondents consistently rejected comprehensive legal FTO at project outset but supported proportionate early IP screening. This refines practitioner recommendations advocating “early FTO” [7], [9] by distinguishing between basic patent intelligence and formal legal FTO. Researchers should conduct initial patent landscape and novelty searches, supported by TTO training, AI-assisted analytics, and institutional guidance, while formal claim- and jurisdiction-specific FTO remains with qualified patent professionals. This differentiation could support common guidelines and more consistent technology transfer practices.

The findings also have implications for research funding. Since patent information represents an important source of technological intelligence [11], [12], [13], funding agencies could strengthen proof-of-concept and validation programmes by encouraging proportionate early IP screening rather than requiring full legal FTO. This could improve novelty assessment, reduce duplication of publicly funded research, and identify licensing or collaboration opportunities before significant resources are committed.

Regarding RQ3, respondents consistently associated early IP assessment with improved research prioritization, identification of technological white spaces, design-around strategies, and commercialization readiness. These findings support studies demonstrating that IP constraints influence innovation trajectories [5], [6], [16] while extending the strategic role of patent information beyond technology monitoring [11], [12]. Early patent intelligence complements, rather than replaces, market validation.

This study is exploratory and based on twelve TTOs from eight Central and Eastern European countries; consequently, the findings provide analytical rather than statistical generalization. Future research should examine the perspectives of researchers, industry, patent professionals, and funding agencies, and evaluate whether the proposed staged governance model improves commercialization outcomes and the efficiency of publicly funded R&D.

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Legal Interoperability and Intellectual Property Governance for AI-Ready Research Data Infrastructures

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Abstract

Artificial intelligence (AI) increasingly depends on research data infrastructures that enable access to datasets, software, models and other digital resources. Yet technical accessibility and FAIR compliance do not by themselves establish lawful reusability. This paper examines how legal interoperability can be operationalised in research data infrastructures supporting AI. It applies a desktop-based doctrinal methodology combining EU legislation, Horizon Europe documentation, interoperability and FAIR frameworks, and policy and technical guidance, informed illustratively by Horizon Europe practice. The analysis finds that AI readiness requires systematic identification of ownership, access, licensing, confidentiality, statutory exceptions and other restrictions. Particular attention is given to the text and data mining (TDM) exceptions in Articles 3 and 4 of Directive (EU) 2019/790. The paper positions IP governance as a practical mechanism for implementing legal interoperability and proposes a six-step workflow integrating rights identification, legal-basis assessment, protection and licensing, machine-readable rights information, governance implementation and periodic review.

Keywords

Legal Interoperability, Intellectual Property Governance, Research Data Infrastructures, Artificial Intelligence, FAIR Principles, Horizon Europe, Text and Data Mining

1 Introduction

Research data infrastructures enable discovery, access, sharing and reuse of datasets, software, models and other digital research resources. Their importance is increasing as AI development depends on large volumes of heterogeneous resources. The FAIR principles make licensing and provenance elements of reusability (Wilkinson et al., 2016), while the European Interoperability Framework (EIF) distinguishes legal, organisational, semantic and technical interoperability (European Commission, 2017). Technical access therefore does not necessarily amount to legal permission to reuse. This gap

becomes especially relevant when research resources move beyond the project in which they were generated and are combined with external datasets, software or models for subsequent R&D, technology transfer or commercial exploitation.

For this paper, an AI-ready research data infrastructure is one whose relevant resources are sufficiently discoverable, technically accessible, semantically interpretable and legally documented to enable their lawful assessment and reuse for AI-related purposes. AI readiness does not imply unconditional openness; rather, rights, restrictions and permitted uses should be sufficiently clear to determine whether and under what conditions reuse is possible. This definition therefore adds a legal dimension to conventional technical notions of AI readiness: a resource should not only be processable by an AI pipeline, but its provenance and conditions of use should also be sufficiently transparent for the intended processing to be assessed. In Horizon Europe, this is consistent with the principle of being “as open as possible, as closed as necessary” (European Commission, 2021).

1.1 Methodology

The study applies a qualitative desktop-based doctrinal methodology. Secondary sources comprise EU legislation on IP, data and AI; Horizon Europe grant and Open Science documentation; the EIF; EOSC and FAIR-IMPACT materials; and scholarly literature on FAIR data. The analysis focuses on ownership, access rights, licensing, confidentiality, provenance, statutory exceptions and documentation of reuse conditions. Sources were reviewed comparatively to identify where technical availability may diverge from legal reusability and to derive governance requirements that can be operationalised during the project lifecycle. Practical Horizon Europe experience is used illustratively rather than as an empirical dataset; consequently, the study does not claim statistical representativeness. The proposed workflow should therefore be understood as a practice-oriented conceptual framework requiring further empirical validation.

2 Legal Interoperability and IP Governance

Legal interoperability describes the condition in which applicable rights, obligations and permitted uses are sufficiently clear and compatible to enable lawful combination, processing and reuse (European Commission, 2017; Graber-Soudry et al., 2021; Rouchon et al., 2024). A technically accessible and semantically described dataset may still be unusable for a particular purpose because of copyright, database rights,

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confidentiality, contractual restrictions or data-protection requirements.

EU law does not create a general standalone property right in data as such. Control may instead arise from copyright, the *sui generis* database right, trade-secret protection, contract and data-protection rules (European Parliament & Council of the European Union, 1996, 2001, 2009, 2016a, 2016b, 2019). Horizon Europe further distinguishes Background from Results, making early identification of ownership and access conditions essential (European Commission, 2021). Copyright may protect original documentation, software and qualifying datasets; databases may receive copyright and/or *sui generis* protection; and commercially valuable confidential information may qualify as a trade secret where it is secret, has commercial value because of that secrecy, and is subject to reasonable protective measures (European Parliament & Council of the European Union, 2016b). Personal data do not become trade secrets merely because they are confidential or regulated by the GDPR: the regimes apply independently (European Parliament & Council of the European Union, 2016a, 2016b).

Licensing is central but not exclusive to legal interoperability. Horizon Europe imposes Open Science obligations, while legitimate restrictions may arise from commercialisation, confidentiality, security, personal-data protection or IP considerations (European Commission, 2021). Software licences such as MIT, Apache 2.0 and GPL also impose materially different redistribution conditions. Reciprocal or copyleft obligations may become relevant when software is modified, combined or redistributed, depending on the licence and the technical form of integration. At ecosystem level, these choices sit within the EU strategy for data and the governance frameworks established by the Data Governance Act and Data Act (European Commission, 2020; European Parliament & Council of the European Union, 2022, 2023). Accordingly, legal interoperability must be assessed against the intended reuse rather than treated as an intrinsic characteristic of a resource. A licence that is appropriate for dissemination of an individual output may still create friction when that output is integrated into a broader data space, AI service or proprietary exploitation pathway.

3 AI Training, TDM and Machine-Readable Rights

The distinction between technical access and lawful reuse becomes especially important for AI. Article 10 of the AI Act establishes data-governance requirements for training, validation and testing datasets used by high-risk AI systems, increasing the importance of provenance and documentation (European Parliament & Council of the European Union, 2024). However, lawful AI-related processing cannot be reduced to licensing analysis because the DSM Directive provides statutory TDM exceptions.

Article 3 of Directive (EU) 2019/790 establishes a mandatory exception for reproductions and extractions undertaken by research organisations and cultural heritage institutions for TDM for scientific research where they have lawful access. The covered TDM activity therefore does not require an additional copyright licence. Article 4 provides a broader exception for lawfully accessible content but permits rightsholders to reserve

their rights; for online content, reservations may be expressed through machine-readable means (European Parliament & Council of the European Union, 2019). Legal interoperability therefore does not require licence compatibility in every case: lawful reuse may derive from ownership, contract, licence, statutory exception or another legal basis.

This interaction is reinforced by Article 53 of the AI Act, which requires providers of general-purpose AI models to adopt a policy to comply with Union copyright law and identify and respect Article 4(3) DSM rights reservations (European Parliament & Council of the European Union, 2024). AI-ready infrastructures should consequently distinguish resources licensed for AI reuse, resources potentially covered by Article 3, resources potentially covered by Article 4 where rights are not reserved, and resources requiring further authorisation or assessment.

Rights information should increasingly accompany technical metadata. FAIR reusability already requires clear usage licences and provenance (Wilkinson et al., 2016). In AI-oriented infrastructures, machine-readable rights information can help distinguish resources that are openly licensed, subject to access restrictions, covered by a TDM exception, or dependent on further authorisation. Vocabularies such as the W3C Open Digital Rights Language (ODRL) can express permissions, prohibitions and duties in a machine-processable form (World Wide Web Consortium, 2018). Such metadata cannot replace legal analysis, particularly where GDPR, confidentiality, trade secrets or contractual restrictions apply, but it can make legal conditions more discoverable and reduce uncertainty at scale. This creates a practical bridge between the legal and technical layers of interoperability.

4 Governance Framework for AI-Ready Infrastructures

IP and legal governance should be incorporated at infrastructure design stage rather than deferred until dissemination or exploitation. Consortia should identify relevant datasets, databases, software, models and third-party resources; map ownership, Background and Results; determine applicable restrictions and legal bases; and ensure that technical architectures can carry rights and provenance information needed for downstream reuse. Responsibilities should also be allocated among data stewards, IP or exploitation managers, technical infrastructure managers, legal advisers and, where personal data are involved, data-protection functions. These roles may be combined in smaller projects, but responsibility for the relevant decisions should remain identifiable. Post-project access should also be addressed early because implementation-oriented access rights may be insufficient for long-term sustainability and exploitation. Decisions made during the funded action can otherwise constrain later technology transfer, licensing, commercialisation or AI-related reuse once the consortium has ended.

A six-step workflow is proposed: (1) rights identification—map ownership, Background, Results, third-party rights and confidentiality; (2) legal-basis and access assessment—determine whether reuse relies on ownership, contract, licence, a TDM exception or another lawful basis; (3) protection and licensing strategy—select appropriate protection, dissemination

and licensing approaches; (4) machine-readable rights documentation—record ownership, provenance, licences, restrictions and TDM reservations where applicable; (5) governance implementation—translate decisions into consortium agreements, data-sharing arrangements, repository conditions and responsibilities; and (6) periodic review—reassess rights when resources are updated, combined, transferred or repurposed for AI. The workflow is iterative and should operate throughout the infrastructure lifecycle.

4.1 Lifecycle implementation

The proposed workflow should be applied across the project lifecycle rather than as a one-off legal review. At proposal and grant-preparation stage, partners can identify strategically important Background, anticipated Results, third-party dependencies and intended exploitation pathways. During implementation, Data Management Plans, Consortium Agreements, repository conditions and access policies can be aligned with evolving technical architecture and exploitation decisions. Before publication, transfer or integration into an AI pipeline, the legal basis for the intended reuse should be reassessed, including relevant licences, contractual permissions and statutory exceptions. At project end, sustainability planning should clarify post-project ownership, hosting, maintenance, access and licensing conditions so that an infrastructure does not remain technically available while its legal status becomes uncertain. This lifecycle approach also allows changes in regulation, rightsholder reservations or exploitation strategy to be incorporated through periodic review.

The distinction between FAIRness, openness and legal reusability is particularly important in this context. FAIR resources need not be unrestricted, and open access does not eliminate third-party rights or regulatory obligations. Conversely, a resource that is not openly licensed may still be reusable for a defined purpose where a statutory exception applies. For AI-oriented infrastructures, the practical objective should therefore be legal transparency rather than maximum openness: users should be able to identify the applicable rightsholder, provenance, access conditions, relevant restrictions and legal basis for the intended operation. This supports both research reuse and subsequent exploitation without treating protection and openness as mutually exclusive objectives.

5 Discussion, Limitations and Further Research

The analysis supports a distinction between availability and lawful reusability. A resource can be publicly accessible and FAIR while remaining unsuitable for a particular reuse; conversely, a resource without an open licence may be lawfully processed under an applicable statutory exception. The proposition “technical access does not equal legal reuse” should therefore be qualified: lawful reuse does not always require a licence, but it does require an identifiable legal basis.

The study is doctrinal and practitioner-informed rather than empirically validated and focuses principally on EU and Horizon Europe conditions. Short-term research should pilot the six-step workflow in active Horizon Europe projects, assessing whether rights mapping and machine-readable rights information

improve the speed and reliability of AI-reuse decisions. Such pilots could combine document analysis with interviews involving data stewards, IP managers, infrastructure operators and technical partners, allowing implementation costs and recurring governance gaps to be identified. Longer-term research should compare sectors and jurisdictions and develop measurable indicators of legal AI readiness, including the completeness of provenance, rights metadata and access conditions. Such work could immediately support Data Management Plans, Consortium Agreements, exploitation strategies and infrastructure sustainability planning and, over time, contribute to interoperable governance standards for human and machine assessment of reuse conditions.

6 Conclusions

AI-ready research data infrastructures require more than technical and semantic interoperability: they also require sufficiently clear legal conditions for intended reuse. The EIF already recognises legal interoperability as one of four interoperability layers (European Commission, 2017). Within research data infrastructures, IP governance operationalises an important part of that layer through rights identification, ownership clarification, access arrangements, protection strategies, licensing and rights documentation. These elements are particularly important in AI ecosystems, where datasets, software, models and other digital resources may originate from multiple actors and be combined, processed and reused across organisational and disciplinary boundaries.

Yet licensing is not the only route to lawful reuse. Articles 3 and 4 of the DSM Directive demonstrate that statutory TDM exceptions may independently permit defined processing activities under specific conditions (European Parliament & Council of the European Union, 2019). The proposed workflow therefore asks not simply which licence applies, but more fundamentally which legal basis permits the intended use and what additional rights, restrictions or governance conditions must be considered. This distinction is important because technical access to a resource does not, by itself, establish the legal conditions for its reuse.

Embedding this assessment into infrastructure design can make research resources more transparently, lawfully and sustainably reusable for AI. It can also help anticipate legal barriers before they become obstacles to cross-project reuse, further R&D, technology transfer or commercial exploitation. In practical terms, legal interoperability should therefore be treated as a design requirement and maintained throughout the research and innovation lifecycle, from the identification of Background and initial access conditions to the management, dissemination, exploitation and post-project reuse of Results. Such a lifecycle approach can support the transition from technically accessible research infrastructures towards genuinely AI-ready ecosystems in which legal, organisational, semantic and technical interoperability are addressed in a coordinated manner.

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Collaboration for Greater Patent Breadth and Complexity? Evidence from Slovenian Public Research Organisations

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Abstract

Collaboration between public research organisations (PROs), industry, and other partners is central to open innovation, knowledge transfer, and knowledge valorisation. However, empirical evidence on how different forms of joint patent ownership are associated with patent characteristics remains limited, particularly in smaller innovation systems. This study examines whether different original applicant configurations are associated with patent breadth, patent complexity, and citation-based technological influence. A manually cleaned PatSnap dataset of 1,034 patent families from four major Slovenian PROs was analysed, distinguishing PRO-only, PRO-company (PRO-C), PRO-PRO, and PRO-individual (PRO-I) ownership. PRO-C and PRO-PRO patents involved larger inventor teams and larger patent families than PRO patents. PRO-C patents exhibited broader IPC profiles, whereas PRO-PRO patents had longer documents and more independent claims. After accounting for patent age, forward-citation rates did not differ significantly among applicant configurations, and no significant differences in backward citations were observed. The findings show that joint ownership is more consistently associated with patent breadth and selected dimensions of complexity than with citation-based technological influence, and highlight the importance of distinguishing among co-ownership models when designing open innovation, knowledge valorisation, and intellectual property strategies.

Keywords: public research organisations, open innovation, joint patent ownership, co-patenting, patent breadth, patent complexity, citation

1 Introduction

Collaboration across organisational boundaries has become an important feature of contemporary research and innovation systems. Public research organisations (PROs) interact with other PROs, companies, public authorities, and other actors to generate and valorise knowledge. These interactions reflect open innovation: purposively managed knowledge flows across organisational boundaries [2, 14]. Collaboration may include joint or contract research, researcher mobility, access to infrastructure, licensing, data and know-how transfer, and the joint development of intellectual assets. Patents are among the most visible outputs of these processes and form part of the broader European knowledge-valorisation framework linking research to economic and societal value [15, 16].

Joint patent ownership captures only one outcome of collaboration, not its depth or quality: collaborative inventions may have a single owner, while shared ownership may reflect contractual arrangements. Co-ownership also creates challenges concerning control, licensing, enforcement, costs, and benefit

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distribution [1, 6]. Nevertheless, patent records provide observable evidence of cross-organisational involvement and standardised information on applicants, inventors, families, classifications, documents, claims, and citations, enabling comparisons across ownership configurations.

Empirical evidence linking ownership configurations to patent characteristics remains limited, particularly in smaller innovation systems. Partner type also matters: Walsh et al. [13] associate heterogeneous and university–industry collaboration with invention quality, and customer and supplier collaboration with commercialisation. Co-ownership configurations therefore warrant separate examination.

This study examines four major Slovenian PROs, distinguishing patents owned solely by a PRO, jointly with companies (PRO-C), by multiple PROs (PRO-PRO), or with individual applicants (PRO-I). It asks: *How are original applicant configurations associated with patent breadth, patent complexity, and citation-based technological influence, and do these associations differ by co-owner type?*

The study contributes evidence from the Slovenian public research sector, distinguishing co-ownership configurations and separating patent breadth and complexity from citation-based technological influence to clarify joint patenting's role within open innovation.

2 Methodology

This section describes the dataset, variables, and statistical analyses.

2.1 Data collection

The empirical analysis is based on patent data retrieved from the PatSnap Analytics platform, accessed on 4 - 5 August 2026. PatSnap was selected because it integrates patent information from the world's major patent offices and provides harmonised bibliographic, legal status and patent family data, enabling comprehensive analyses of patenting activities.

The study focuses on the four Slovenian public research organisations with the highest patenting activity: University of Ljubljana, Jožef Stefan Institute, National Institute of Chemistry, and University of Maribor. All patent families associated with these organisations were retrieved from PatSnap. The initial dataset was subsequently manually reviewed to identify and correct inconsistencies in applicant organisational forms and other data quality issues resulting from database inconsistencies. This manual validation ensured that patents were correctly assigned to the respective public research organisations and that other records were removed. The unit of analysis was one patent-family record. Following deduplication, the final dataset comprised 1,034 observations.

2.2 Variables

To investigate the relationship between collaborative patenting and patent characteristics, patents were classified according to the ownership structure into four applicant categories:

- PRO – patents owned solely by a public research organisation;
- PRO-PRO – jointly owned by two or more public research organisations;
- PRO-C – jointly owned by a public research organisation(s) and a private company(es);
- PRO-I – jointly owned by a public research organisation and one or more individual applicants (natural persons).

The four categories were mutually exclusive. Patents involving at least one company co-applicant were coded as PRO-C; patents involving multiple PROs but no company were coded as PRO-PRO; and patents involving individual co-applicants but no company or additional PRO were coded as PRO-I.

Patent characteristics were measured using a set of bibliometric and patent value indicators available in PatSnap.

2.3 Data analysis

Descriptive statistics were first used to characterise the patent portfolio and the distribution of applicant types.

To analyse differences among the four applicant types (PRO, PRO-PRO, PRO-C and PRO-I), one-way analysis of variance (ANOVA) with Tukey's HSD post hoc test was conducted. Additionally, because forward citations accumulate over time, patent age was calculated as the period between the application date and the data-collection date (5 August 2026). An annual forward-citation rate was calculated by dividing the number of forward citations by patent age in years. Differences in application year and annual forward-citation rates among applicant types were assessed using Welch's ANOVA because the assumption of homogeneity of variance was violated. Games–Howell post hoc comparisons were used to compare annual forward-citation rates between applicant types.

All statistical analyses were performed using JASP (version 0.19.2). Statistical significance was assessed at the 5% significance level ($p < 0.05$).

3 Hypotheses development

This section develops hypotheses concerning patent breadth, complexity, and citation-based indicators.

3.1 Patent breadth

Patent breadth is examined through inventor-team size, patent-family size, and document length. Organisational co-ownership may combine complementary expertise and involve larger inventor teams, although applicant and inventor counts are distinct. Inventor-team size remains comparatively underexplored [9], while co-patenting studies highlight the importance of partner type and relationship structure [1, 10].

Larger patent families may indicate broader protection strategies and resource commitments, although their interpretation depends on family definitions and filing practices [5, 7]. Geographical coverage is a related indicator [9], but the application count used here is not equivalent to the number of countries covered. Neither measure directly establishes commercial success. Evidence linking co-ownership to citation-based quality [4] motivates

examining whether it is also associated with larger families. Integrating technical elements and knowledge from multiple partners may additionally require longer documents, particularly in PRO-PRO collaborations.

H1a. PRO-C and PRO-PRO patents involve larger inventor teams than PRO patents.

H1b. PRO-C and PRO-PRO patents have larger simple patent families than PRO patents.

H1c. PRO-C and PRO-PRO patents have longer patent documents than PRO patents.

3.2 Patent complexity

Patent complexity concerns technological and legal structure, represented here by IPC classifications and patent claims. PRO-C collaborations may combine scientific and application-oriented expertise, while PRO-PRO collaborations may integrate scientific disciplines. Partner type, technological relatedness, previous ties, and geographical distance can influence co-patenting outcomes [1, 10]. Such knowledge combinations may produce broader IPC profiles, although classification practices vary across fields and time.

Claims define the protection sought: total claims cover different aspects or embodiments, while independent claims stand without reference to another claim. Combining partners' knowledge and interests may require more elaborate claim structures, reflecting technological complexity or differentiated protection strategies rather than necessarily higher quality.

H2a. PRO-C and PRO-PRO patents have broader IPC classification profiles than PRO patents.

H2b. PRO-C and PRO-PRO patents contain more patent claims than PRO patents.

H2c. PRO-C and PRO-PRO patents contain more independent claims than PRO patents.

3.3 Knowledge base and technological influence

Backward citations identify prior-art knowledge inputs [11], whereas forward citations indicate subsequent technological influence through references from later patents [12]. Combining partners' knowledge may broaden the cited knowledge base and increase an invention's relevance to subsequent developments. However, backward citations also reflect technological field, patent-office procedures, examiner practices, and jurisdiction. Forward citations are sensitive to patent age, field, office practices, and citation windows [8].

Briggs and Wade associate joint ownership with higher innovation quality measured by forward citations [4]. Nevertheless, citation outcomes may vary with partner type, relationships, and collaboration context [1, 3, 10]. These considerations motivate testing both citation dimensions separately.

H3a. PRO-C and PRO-PRO patents have more backward citations than PRO patents.

H3b. PRO-C and PRO-PRO patents receive more forward citations than PRO patents.

4 Results

This section presents descriptive statistics and hypothesis tests.

4.1 Descriptive overview

The final dataset comprised 1,034 patent families from four Slovenian public research organisations. As shown in Table 1, PRO-only patents accounted for 74.4% of the sample, followed by PRO-C (15.1%), PRO-PRO (8.5%), and PRO-I patents (2.0%).

Table 1. Applicant configuration in the cleaned sample

Applicant configuration	Number	Percentage
PRO	769	74.4%
PRO-C	156	15.1%
PRO-PRO	88	8.5%
PRO-I	21	2.0%
Total	1,034	100.0%

Table 2 shows that the joint-ownership categories do not have the same profile. PRO-C and PRO-PRO patents have larger inventor teams and patent families. PRO-I patents show a different pattern: relatively small families and teams, but higher average values for annual forward-citation rates and independent claims. Because the PRO-I group contains only 21 records, a few unusual patents can strongly affect its averages.

Table 2. Mean values by the applicant configuration

Indicator (mean)	PRO	PRO-C	PRO-PRO	PRO-I
Inventors	3.16	5.03	5.75	3.35
Simple-family members	1.85	2.58	2.99	1.67
Document pages	15.79	19.61	22.93	11.19
IPC classifications	2.47	3.55	3.13	2.91
Total claims	16.26	13.71	18.23	12.15
Independent claims	0.86	0.83	2.27	2.62
Backward citations	1.03	1.42	2.18	1.48
Forward citations per year	0.023	0.038	0.023	0.095

Note. Sample sizes vary across indicators because of missing data.

4.2 Hypotheses testing

This section reports hypothesis tests; detailed tables and post hoc comparisons are available on Zenodo: <https://doi.org/10.5281/zenodo.21968175>.

4.2.1 Patent breadth

Applicant configuration was associated with inventor-team size, $F(3, 1012) = 53.246$, $p < .001$, and simple-family application count, $F(3, 1030) = 14.658$, $p < .001$. PRO-C and PRO-PRO patents had larger teams and families than PRO patents (all Tukey-adjusted $p < .001$), supporting H1a and H1b. Team size did not differ significantly between PRO-C and PRO-PRO; family size did not differ significantly between PRO-I and PRO. Document length differed significantly, $F(3, 997) = 6.828$, $p < .001$. PRO-PRO documents were longer than PRO documents (Tukey-adjusted $p = .001$), whereas the PRO-C–PRO difference was not significant ($p = .058$), partially supporting H1c.

4.2.2 Patent complexity

IPC classification count differed significantly, $F(3, 1030) = 8.620$, $p < .001$. PRO-C patents had more classifications than PRO patents (Tukey-adjusted $p < .001$), but PRO-PRO patents did not ($p = .103$). H2a was partially supported.

Total claim count showed no significant differences, $F(3, 301) = 1.950$, $p = .122$, and no Tukey comparison was significant. H2b was unsupported. Missing data restricted this analysis to 305 of 1,034 patent families, potentially reducing statistical power.

Independent claim count differed significantly, $F(3, 1030) = 15.598$, $p < .001$. PRO-PRO patents had more independent claims than PRO patents (Tukey-adjusted $p < .001$), whereas PRO-C patents did not ($p = .998$). PRO-I patents also exceeded PRO and PRO-C patents significantly. H2c was partially supported.

4.2.3 Knowledge base and technological influence

Backward citation count showed no significant differences, $F(3, 1030) = 2.357$, $p = .070$. No Tukey comparison was significant, including PRO-PRO versus PRO ($p = .057$). H3a was unsupported.

Application year differed significantly across configurations (Welch's $F(3, 81.01) = 23.59$, $p < .001$), indicating distinct age profiles. After normalisation by patent age, annual forward-citation rates did not differ significantly, Welch's $F(3, 81.21) = 1.18$, $p = .323$; all Games–Howell comparisons were also non-significant. Neither PRO-C nor PRO-PRO showed the hypothesised advantage over PRO, leaving H3b unsupported. PRO-I's higher descriptive rate was not statistically significant and warrants caution given its small sample ($n = 21$).

5 Discussion and conclusion

In the corporate patenting literature, joint ownership is often viewed as a second-best option, although some evidence associates it with higher innovation quality [4]. The present study provides a more differentiated picture: jointly owned patents differ from PRO-only patents in selected characteristics, but the patterns depend on co-owner type and do not establish a general quality advantage. Joint ownership should therefore not be treated as a uniform indicator of collaboration or open innovation.

The clearest pattern concerns patent breadth. PRO-C and PRO-PRO patents have significantly larger inventor teams and simple patent families than PRO patents, indicating broader participation and more related applications. INPADOC results are similar but not presented. Larger families do not necessarily imply broader international protection without accounting for

filing routes and temporal differences. PRO-PRO documents are significantly longer than PRO documents; the PRO-C–PRO difference is not significant. Joint patenting thus captures organisational, protection-related, and documentary breadth, but not all collaborative activities.

Complexity patterns vary. PRO-C patents have significantly broader IPC profiles than PRO patents, potentially reflecting integration of scientific and application-oriented, engineering, production, or market expertise; these mechanisms remain untested. The higher PRO-PRO IPC mean is not significant. PRO-PRO patents have significantly more independent claims than PRO patents, whereas PRO-C patents do not, potentially indicating differentiated technical components or protection strategies rather than higher quality. Total claims show no significant differences, but availability for only 305 of 1,034 families limits statistical power and potentially representativeness.

Backward citations show no significant differences across configurations, including between PRO-PRO (the highest descriptive mean) and PRO; H3a is unsupported. They capture cited prior art imperfectly as a measure of knowledge sourcing, also reflecting patent office procedures, examiner practices, the technological field, and jurisdiction.

Application year differs significantly across configurations, indicating different age profiles. After dividing forward citations by patent age, neither Welch's ANOVA nor Games–Howell comparisons identify significant differences in annual rates. PRO-I has the highest descriptive annual citation rate, but its differences from the other groups are not statistically significant and its small sample (21 families) warrants caution. Neither PRO-C nor PRO-PRO shows the hypothesised advantage over PRO, leaving H3b unsupported. Together, these findings show why co-owned patents should not be analysed as a homogeneous category. PRO-C and PRO-PRO patents exhibit distinct profiles, and such patterns may reflect different mechanisms of knowledge integration, intellectual property allocation, and protection strategy. This interpretation is consistent with research highlighting the relevance of partner type, previous ties, technological relatedness, and geographical distance to co-patenting outcomes [1, 10].

For research and innovation policy and technology transfer offices, these differences suggest that PRO-C and PRO-PRO partnerships may require different intellectual property arrangements that reflect partners' objectives, resources, incentives, and intended uses of the results. Prior literature identifies both potential benefits and management difficulties associated with joint ownership [1, 6]. Practical arrangements should therefore clarify filing costs, licensing, enforcement, transfers, and decision-making. The appropriate ownership model depends on partners' contributions and plans to exploit the results, rather than on the assumption that co-ownership is inherently preferable.

This differentiated approach is also consistent with the broader European knowledge-valorisation framework [15, 16]. Policy evaluation should combine co-patenting data with information on collaborative projects, licences, contract research, spin-offs, repeated partnerships, and the actual use of research results. Patents alone cannot capture the economic and societal value of collaboration.

The study is limited to four Slovenian PROs, with uneven applicant-group sizes, substantial missing total-claim data, and the constraints of patent-based indicators. Future research should combine patent records with broader data on collaboration and commercialisation to better assess the benefits of different partnership models. Overall, the findings suggest that collaboration can offer benefits beyond citation-based technological influence: organisational co-ownership is associated with larger inventor teams, larger patent families, and, depending on partner type, more differentiated patent structures. These patterns provide a positive case for collaboration while highlighting the importance of selecting suitable partners and ownership arrangements.

Data availability: The data and tables supporting the findings of this study are available in Zenodo at <https://doi.org/10.5281/zenodo.21968175>

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Digital Educational Platforms as Innovation-Enabling Infrastructures: A Quadruple-Helix Framework

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Abstract

Digital platforms are integral to educational administration, communication, and learning, while also generating data relevant to research, technological development, and policy. This conceptual paper proposes an education-specific Quadruple-Helix framework in which digital educational platforms are understood as innovation-enabling infrastructures rather than innovation intermediaries. They provide a technological environment for exchanging data, knowledge, needs, solutions, and feedback among schools, researchers, technology providers, and policymakers. The framework extends beyond traditional technology transfer to include knowledge exchange, co-creation, and open innovation. The Slovenian educational context and existing e-administrative platforms illustrate the proposed approach. The paper also considers key conditions for its implementation, including data governance, interoperability, stakeholder participation, and institutional capacity. Overall, the framework shows how existing digital infrastructures may strengthen connections between educational practice, research, technology development, and policy.

Keywords

Digital educational platforms, Quadruple Helix Framework, educational innovation, knowledge exchange, co-creation, collaborative governance

1. Introduction

The transformation of digital technologies in recent years has changed the way educational institutions organize their administrative, communicative, and learning processes. Different activities that were previously managed through separate procedures are now efficiently connected in Student Information Systems (SIS), Learning Management Systems (LMS), and other digital educational platforms. These systems not only support administration, communication, and learning but also generate substantial

amounts of data, such as attendance, learning processes, educational needs, engagement, and institutional performance [4]. Despite this development, the innovation potential of such platforms is frequently considered secondary to their operational role. In addition to serving as administrative infrastructures, the primary argument presented in this paper is that digital educational platforms have the potential to function as innovation-enabling infrastructures. By connecting educational practice with research, technology development, and public policy, platforms may facilitate the movement of data, knowledge, feedback, and technological solutions across institutional boundaries.

The platform itself is not understood as an innovation intermediary or an autonomous innovation actor. Rather, it provides a technological environment through which innovation intermediation and collaboration among different actors may take place.

Taking this perspective into consideration is especially important when discussing the transfer of knowledge and technology. The transfer of knowledge and technologies from universities and research organizations to industry has often been a central focus of traditional technology transfer strategies [2]. Contemporary innovation ecosystems, however, increasingly emphasize co-creation, open innovation, networking, and knowledge valorization. Educational institutions can participate in these processes because they have contextual knowledge about real-world problems, user needs, and the conditions under which they implement technologies. Within such a setting, what is exchanged is not limited to technology but may also include educational needs, contextual knowledge, data, research findings, user feedback, and digital solutions. Technology transfer can therefore be understood as one element of a broader process of knowledge exchange and co-creation.

This paper, therefore, proposes a Quadruple-Helix framework for understanding how digital educational platforms may support knowledge exchange, co-creation, and technology transfer among four stakeholder groups: educational institutions, research organizations, technology providers, and policymakers. The framework represents an education-specific adaptation of the Quadruple-Helix model, in which these four groups reflect the functions of the societal/practice, academic, industry, and government dimensions of the model. The paper uses the Slovenian educational context as an illustrative setting and focuses particularly on the role of e-administrative and educational data infrastructures.

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2. From Digital Platforms to Innovation-Enabling Infrastructure

In traditional educational administrative systems, data were primarily collected for operational purposes: recording attendance, grades, enrollment, communication, or compliance. Contemporary platforms increasingly allow different types of information to be aggregated and connected, resulting in a growing volume of educational data.

However, the existence of this data does not automatically produce better or more innovative decisions. If data, generated through everyday educational processes and observations, is interpreted in relation to a specific educational problem, it must be transformed. Research can help to transform data and observations into validated knowledge, while technology can translate some of the obtained knowledge into digital solutions [6]. If the necessary conditions are met, policymakers and institutional leaders can, in turn, influence whether such solutions can be implemented and, where appropriate, adopted more widely.

From this perspective, educational innovation can be understood not as a linear process, but as a continuous and iterative process [13], in which data, research, knowledge, technological development, implementation, and feedback interact over time, as seen in Figure 1.

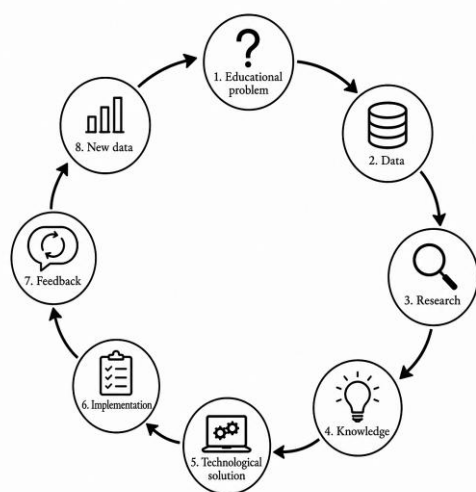


Figure 1: Innovation process as a continuous cycle

The cycle can be summarized as: *Educational problem* → *Data* → *Research* → *Knowledge* → *Technological solution* → *Implementation* → *Feedback* → *New data*

Importantly, not every educational problem has to lead to a technological solution. It shows, rather, that data, research, implementation, and feedback can become a part of this continuing process of improvement. In some cases, the results may be a new digital tool; in others, a modification of an existing platform, e.g., a change of an institutional practice or a policy decision.

From this viewpoint, we can see a digital educational platform as part of an emerging innovation infrastructure. The significance of such a platform lies not just in storing or processing data, but also in providing a shared technological environment that can

support connections between practical knowledge, formal research, development activities, and decision-making.

3. An Education-Specific Quadruple Helix Framework

The Quadruple-Helix model provides a useful conceptual framework, as it emphasizes interaction among research, industry, government, and the wider public or societal environment rather than treating innovation as a bilateral relationship between academia and industry [3].

The framework proposed in this paper represents an *education-specific adaptation* of this model. The four helices are translated into schools and educational institutions, research organizations, technology providers, and policymakers. This is not intended as a direct replacement of the classical Quadruple Helix, but as a way of identifying the actors that perform comparable functions within an educational innovation ecosystem. Research organizations represent the knowledge-production and analytical function traditionally associated with academia. Technology providers represent the technological and development capacity generally associated with industry. Policymakers and public authorities represent the government and its regulatory, funding, and coordinating roles. Schools and educational institutions represent the practice-oriented and societal environment in which educational needs emerge, and innovations are ultimately used. Within the proposed framework, the four groups have related but distinct roles:

(i) *Schools and educational institutions* are not simply locations where technologies are implemented. By connecting teachers, learners, families and communities, they contribute contextual knowledge that cannot be fully captured through administrative data and link formal innovation systems with everyday educational practice. [11].

(ii) *Research organizations* represent academia, technology providers the industry dimension, policymakers the governmental dimension, and schools the societal and practice-oriented environment in which educational needs emerge and innovations are implemented [7].

(iii) *Technology providers* turn identified needs and research knowledge into digital products, services, and functionalities. Their expertise is particularly useful in the area of customizing technological solutions to institutional workflows, interoperability requirements, or user needs [8].

(iv) *Policymakers and public authorities* create the institutional environment in which innovation takes place. They influence funding, regulation, procurement, data governance, interoperability, and the possibility of scaling successful solutions across educational systems. Figure 2 shows these actors together within a shared digital environment.

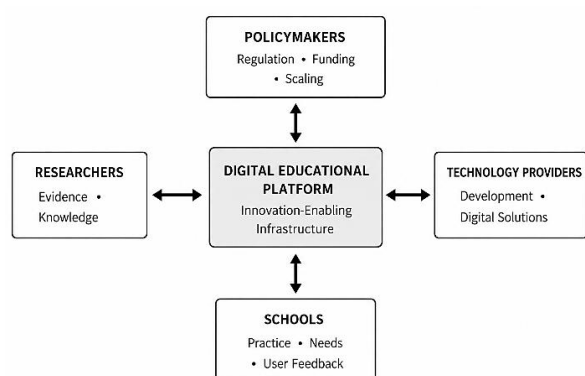


Figure 2: An Education-Specific Quadruple-Helix Framework for Digital Educational Platforms

The digital educational platform occupies the center of the framework, but its presence does not make it a fifth actor. It should instead be understood as the *infrastructure* through which interactions among the four actors may be supported.

The interactions within this framework do not need to follow one predefined direction. Research may identify requirements for technological development. Implementation of a technological solution may generate new data or reveal unexpected difficulties. These findings may then require changes in technology, institutional practice, or policy.

The framework, therefore, moves away from a simple linear model of technology transfer. Technology can certainly be transferred or developed within this process, but the wider process involves reciprocal *knowledge exchange and co-creation*. Its effectiveness depends on whether the actors have meaningful opportunities to communicate, interpret information together, and influence decisions.

4. The Slovenian Education Context

The Slovenian educational context provides an illustrative setting for considering how the proposed framework could operate in practice. The examples discussed in this section should not be understood as empirical case studies or as evidence that the proposed Quadruple-Helix relationships already exist. Rather, they illustrate the types of digital infrastructures that are currently present in educational practice. Platforms such as eAsistent [14] or LoPolis PRO [15] show how information concerning students, educational processes, and institutional administration can already be digitally recorded, managed, and made available to authorized users.

Their immediate purpose is largely operational. Nevertheless, the types of information managed through such platforms may also point to broader educational questions. Patterns in attendance, achievement, engagement, or identified learning needs, for example, may raise questions that are relevant to teachers, researchers, or institutional decision-makers. Such questions could lead to further research, changes in educational practice, or the development of new platform functionalities.

However, this possibility should not be confused with an assumption that the platforms automatically create innovation. A technical infrastructure may exist while the institutional

relationships needed for collaborative innovation remain weak or fragmented.

For the proposed framework to operate in practice, communication and cooperation would need to be established among schools, researchers, technology providers and public authorities. Schools would need meaningful opportunities to articulate problems and evaluate proposed solutions. Researchers would need appropriate and ethically governed access to relevant questions and, where justified, data. Technology providers would need mechanisms for responding to evidence and user needs. Policymakers would need to create conditions in which useful solutions can be responsibly implemented and evaluated.

The Slovenian examples therefore illustrate both an opportunity and a limitation. Existing platforms show that much of the basic digital infrastructure is already present. The more difficult question is whether the institutional arrangements surrounding these infrastructures can support sustained knowledge exchange and co-creation.

5. Conditions and Challenges

Several questions and challenges arise when positioning digital educational platforms as innovation-enabling infrastructures.

(i) *Data governance*. Educational data is sensitive. Its availability within a platform does not mean that they can automatically be used for research, innovation or technology development. Purposes, responsibilities, access conditions and safeguards need to be clearly defined [5]. The potential value of data therefore needs to be considered together with privacy, ethical use and accountability.

(ii) *Technical connectedness and interoperability*. If platforms operate as isolated systems, data and knowledge remain institutionally fragmented. Technical connectedness and interoperability therefore become an important condition for knowledge distribution and wider innovation ecosystems [9]. At the same time, interoperability should not be understood simply as unrestricted data exchange; it needs to operate within appropriate governance arrangements.

(iii) *Technology providers*. Technology providers often have more technical expertise and financial resources compared to individual schools. The danger is that when such suppliers largely determine the innovation processes, educational institutions become passive consumers of technology, not active co-creators [10].

(iv) *Teachers and co-design*. There is a risk of transforming teachers into data providers. Educational practice contains forms of implicit and contextual knowledge that cannot be fully represented through platform data. Teachers therefore need to remain active participants in problem definition, interpretation, evaluation and co-design [1].

(v) *Institutional capacity*. The institutional organization and capacity matters. Effective Quadruple-Helix collaboration requires time, coordination mechanisms, competencies and incentives. Without institutional support, collaboration may depend on individual enthusiasts and remain difficult to sustain [12].

These challenges suggest that the central issue is not technology alone. Whether digital platforms can support educational innovation depends at least as much on governance, institutional relationships and participation as it does on technical capacity.

6. Conclusion

Digital educational platforms are usually introduced to support administration, communication, information management, or learning. This paper argues that their role can be broader when they are understood not as innovation intermediaries themselves, but as innovation-enabling infrastructures supporting collaboration among schools, researchers, technology providers, and policymakers.

The proposed education-specific Quadruple-Helix framework extends the perspective beyond traditional technology transfer. What circulates among the actors includes educational needs, contextual knowledge, data, research evidence, feedback, and technological solutions. Technology transfer can therefore be seen as part of a broader process of knowledge exchange and co-creation.

The Slovenian examples, eAsistent or LoPolis PRO, illustrate that some of the necessary digital infrastructure is already present, although an innovation ecosystem does not emerge automatically from technology. Data governance, interoperability, institutional capacity, trust, and stakeholder participation remain important conditions. Future research should examine these relationships empirically and explore when digital educational infrastructures can support sustained knowledge exchange and collaborative innovation.

Ultimately, the value of a digital educational platform lies not only in the information it stores or the administrative processes it supports, but also in its potential to connect different forms of knowledge and the actors who hold them.

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Technology Transfer Office in an Emerging Innovation Ecosystem: Institutional Preconditions and Capacity-Building Priorities in Montenegro

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Abstract

Technology Transfer Offices (TTOs) are important intermediaries between research organizations, firms and public institutions, particularly in small and emerging innovation ecosystems. This paper examines the early development of Montenegro's national TTO through an exploratory conceptual case-study approach. It draws on peer-reviewed literature, official policy and institutional documents, publicly available sources, and descriptive institutional information on activities initiated by the TTO. Because systematic interviews, observations, and longitudinal performance data are not yet available, the paper does not claim measured effects on commercialization or national competitiveness; competitiveness is treated only as a potential long-term consequence of improved innovation capacity. The analysis distinguishes between current or initiated activities, institutional preconditions and recommended capacity-building priorities. It suggests that early-stage effectiveness depends on a clear mandate, stable financing, professional competences, intellectual property rules, researcher incentives and integration with the wider innovation ecosystem. The paper proposes that early-stage TTOs should also be assessed through capacity-building indicators, such as researcher training, invention disclosures, IP consultations, research-capacity mapping and proof-of-concept opportunities, rather than only through patents, licenses, spin-offs or licensing income.

Keywords

Technology Transfer Office, Montenegro, knowledge transfer, innovation ecosystem, capacity building, intellectual property, university–industry cooperation

1 Introduction

Technology transfer is an important component of contemporary innovation policy. Universities and public research organizations are increasingly expected not only to generate scientific knowledge, but also to support its translation into economic and

societal value. TTOs serve as intermediaries between researchers, companies, investors, and public authorities.

Technology transfer is not a linear process. Its effectiveness is shaped by transfer agents, institutional rules, incentives, market conditions and the absorptive capacity of firms [1]. University–industry relations also include collaborative and contract research, consulting and informal cooperation, rather than only patenting and licensing [2].

In small and emerging innovation ecosystems, these intermediary functions can be especially important because research capacity, university–industry cooperation, private R&D investment and experience with intellectual property management may be limited. In such settings, a TTO can help create the organizational routines and relationships needed for later commercialization.

Montenegro provides a relevant case for examining this early stage. Previous work argues that a TTO can support innovation and economic development by improving research commercialization and links between science and business [3], but the national office is still too new for mature outcome assessment. The research question is therefore: Which institutional, organizational and cultural preconditions are necessary for the effective operation of the Montenegrin TTO, and which capacity-building priorities are most appropriate during its early development?

2 Theoretical background

Technology transfer refers to the movement and application of knowledge, technologies, inventions, intellectual property, research results, and expertise from research organizations to industry, public institutions, or society. The Triple Helix model frames innovation as interaction among universities, industry, and government [4], with the TTO acting as an institutional bridge among these actors.

TTOs commonly support invention identification, IP protection, licensing, spin-off creation, contract research, industry matchmaking and researcher education. Their performance depends not only on resources, but also on organizational practices and the institutional environment [5]. Academic engagement research likewise shows that knowledge transfer extends beyond formal IP transactions [2].

For early-stage TTOs, patents, licenses and spin-offs are therefore insufficient as stand-alone performance measures. Broader indicators are needed to capture awareness raising,

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institutional learning, researcher support, networking and the establishment of formal procedures [6]. Recent reviews also describe TTOs as ecosystem intermediaries supporting entrepreneurship, university–industry collaboration, proof-of-concept development and innovation services [7][8].

A stage-sensitive view also distinguishes commercial outputs from the capabilities that make those outputs possible. Before licensing income or spin-offs can reasonably be expected, a TTO must help create a pipeline from awareness and disclosure through assessment, proof-of-concept work and partner engagement. In a new office, limited mature outputs do not necessarily imply a lack of institutional progress if these intermediate capabilities are being established. This does not replace output measures; it places them later in the evaluation sequence. For Montenegro, the distinction provides the conceptual basis for separating current activities, enabling conditions and future priorities [6][8].

3 Montenegro context for innovation

Montenegro is a small open economy seeking to strengthen innovation capacity and align research and innovation policy with European priorities. Its innovation infrastructure includes the Science and Technology Park of Montenegro and support mechanisms for start-ups and innovation-oriented enterprises [9]. Since 2024, the national TTO has operated within the Science and Technology Park through a cooperation framework involving the Government of Montenegro, the Ministry of Education, Science and Innovation, the University of Montenegro and the Science and Technology Park [10]. In the Global Innovation Index 2025, Montenegro ranked 64th among 139 economies, with innovation outputs weaker than inputs [11]. This provides contextual evidence of an innovation input–output gap, but does not establish an effect of the TTO.

Prior work on Montenegro suggests that technology-transfer mechanisms may strengthen links between research institutions and the economy [3]. Related work on national technology-transfer frameworks emphasizes the importance of IP rules, funding, institutional coordination, and professional skills for commercialization [12]. These sources motivate an analysis of enabling conditions rather than an impact claim.

4 Methodology

This paper uses an exploratory conceptual case-study design because the Montenegrin TTO is still at an early stage and longitudinal outcome data are not yet available. The design is intended to identify and structure relevant conditions and priorities, not to estimate causal effects.

The analysis draws on: (i) a review of peer-reviewed literature on technology transfer, TTOs, Triple Helix theory and university–industry cooperation; (ii) official policies, strategies and public institutional sources concerning Montenegro's innovation system; and (iii) descriptive institutional information on activities initiated by the TTO.

The conceptual synthesis is organized around five domains derived from the literature: mandate and governance, financing, professional capability, IP and incentive arrangements, and ecosystem connectivity. Descriptive information on current TTO activities is considered against these domains to identify gaps and formulate priorities. This is a structured interpretive exercise

rather than a formal qualitative coding protocol; no frequency counts or causal inferences are made.

To keep evidence and recommendations distinct, the paper separates three analytical categories: current or initiated activities, institutional preconditions and recommended future measures. The latter two categories are interpretive and normative. The absence of interviews, systematic observations and longitudinal performance data is the main limitation and precludes claims that the TTO has already produced measurable commercialization or competitiveness effects.

5 Current and initiated activities

Current activities are reported descriptively and are not treated as performance results. Based on institutional information supplied by the authors and the cited public sources, the TTO has initiated:

- mapping of national research capacities and laboratory infrastructure;
- technology-transfer and IP awareness activities for researchers;
- development of invention-disclosure and commercialization-support procedures;
- guidance on commercialization pathways and relevant European funding instruments;
- facilitation of contacts among research institutions, innovative companies and public authorities;
- patent-information and IP-protection assistance through the Montenegro PATLIB Centre (IP4Innovation) [14].

6 Institutional preconditions for effective operation

The literature and policy context point to six interrelated preconditions for effective early-stage operation:

- a clear mandate covering IP support, commercialization advice, matchmaking, researcher training and coordination with ecosystem actors;
- stable public and institutional financing, because early licensing income is unlikely to sustain a new office;
- professional competences in IP, law, business development, negotiation, research funding, project management and communication [5];
- clear institutional IP rules on ownership, revenue sharing, disclosure obligations, conflicts of interest, licensing and spin-offs;
- researcher incentives that recognize applied projects, IP activity and industry cooperation alongside publication outputs;
- integration with universities, the Science and Technology Park, innovation funds, ministries, firms, investors and relevant European networks.

7 Recommended capacity-building priorities

Given the TTO's early stage, the following measures are proposed as future priorities rather than reported as achieved outcomes:

- systematic IP-awareness and researcher-outreach programmes;
- a functioning invention-disclosure, triage and referral process;
- a regularly updated map of laboratories, research teams, technologies and applied expertise;
- a proof-of-concept pathway for validation, prototyping and market testing, reflecting the importance of gap-bridging instruments [13];
- repeated industry-engagement and pilot mechanisms that can gradually build trust between researchers and firms;
- gradual support for academic entrepreneurship, including licensing, spin-off readiness, ownership models and investment preparation.

8 Discussion and conclusion

The Montenegrin TTO should be evaluated according to its stage of development. Appropriate early indicators include researchers trained, invention disclosures received, IP consultations provided, research teams mapped, company meetings organized, collaborative project ideas developed and proof-of-concept opportunities identified. These are capacity-building indicators; they are not evidence of changes in national competitiveness.

The analysis is consistent with prior work that positions TTOs as mechanisms for research commercialization and university–industry cooperation [3][12]. It suggests, rather than demonstrates, that the Montenegrin TTO can function as a developmental intermediary if its mandate, financing, competences, IP governance, researcher incentives, and ecosystem integration are strengthened.

The paper's main contribution is a stage-sensitive framework that separates current activities from enabling preconditions and future measures, while proposing capacity-building indicators for an early-stage TTO. Potential effects on innovation capacity and competitiveness should be treated as long-term propositions to be tested, not as observed outcomes of the present study.

The proposed evaluation logic is intentionally sequential. In the earliest phase, awareness, research mapping, disclosure routines, and trusted contact points should create a flow of potential cases. A second phase requires proof-of-concept support, market validation, and repeated company engagement. Only after a more stable deal flow develops do mature indicators such as patent portfolios, licensing income, spin-offs and investment become central. This sequence also clarifies the competitiveness issue: any contribution to national competitiveness would be indirect and long-term, mediated by stronger knowledge transfer, commercialization and innovation outputs rather than observable from the present TTO activities alone [6][8][12][13].

For policymakers, early accountability should therefore combine activity and capability indicators with explicit milestones for transition towards outcome metrics. Such a balanced approach can avoid both underestimating a new TTO because licensing

revenues are initially low and overstating its impact before empirical evidence becomes available.

Future research should add interviews with researchers, companies, TTO staff and policymakers, systematic observation and longitudinal monitoring of disclosures, IP consultations, collaborative projects, patent applications, licensing and spin-off activity. Such evidence would allow later assessment of relationships between TTO activity, commercialization outcomes and wider innovation performance.

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From Programme Status Quo to Institutional Evaluation: The Development of Research Assessment in the Slovenian Research System, 2004–2026

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Abstract

This article traces the development of research assessment in Slovenia from the establishment of the Slovenian Research Agency (ARRS) in 2004 to the pilot external institutional evaluation of 2026. The study uses longitudinal documentary and institutional analysis of legislation, official evaluation documents, European reform frameworks and primary policy-development materials. It asks how the object, evidential basis, decision authority and consequences of assessment changed across successive governance models. The former programme system periodically evaluated research programmes, but its financial design primarily protected institutional continuity. The 2021 Scientific Research and Innovation Activities Act established the Slovenian Research and Innovation Agency (ARIS), introduced stable funding and institutional accountability, while a 2022 formula risked substituting funding structure for quality and impact. The subsequent reform moved towards open science and responsible assessment. The 2025 proto-evaluation assessed all 54 stable-funding recipients against three common criteria and introduced a draft-response-final sequence, exposing the need to distinguish factual correction, clarification and substantive reconsideration. The 2026 model adds continuous self-evaluation, qualitative assessment of outputs and societal impact, the institutional research environment and a site visit. The article's added value is a single longitudinal institutional account connecting these stages. It concludes that credibility now depends on transparent procedures, comparable treatment across heterogeneous organisations and a clear boundary between correction and reassessment.

Keywords

research assessment; ARRS; ARIS; stable funding; research programmes; institutional evaluation; open science; CoARA; societal impact.

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1 Introduction and Evidential Basis

Research assessment is not merely a technical measurement of quality. It defines admissible achievements, allocates authority among the ministry, ARRS or ARIS, research organisations and reviewers, and determines whether judgment affects funding, organisation and careers. This study was undertaken because the current Slovenian model cannot be understood as a simple technical shift from metrics to peer review: between 2004 and 2026, successive arrangements changed what was assessed, which evidence counted, who exercised decision authority and how judgments affected funding and organisational development. Reconstructing that sequence is important because the legitimacy of institutional evaluation depends on whether the new qualitative model overcomes the continuity bias and proxy problems of earlier arrangements without creating new procedural vulnerabilities. The article asks how the object, methods, consequences and legitimacy of assessment changed between 2004 and 2026. Its added value is connecting the former programme regime, the 2022 allocation formula, the 2025 proto-evaluation, and the 2026 institutional model within one longitudinal institutional framework. Figure 1 summarises the main stages of this development.

The study uses longitudinal documentary and institutional analysis. It combines legislation and official instructions [1–13], European reform documents [14–22], and primary working materials [23–31]. The study obtained all documentary data from publicly accessible sources or through access procedures under the Slovenian Access to Public Information Act (ZDIJZ) [32]. Sources are not treated as equivalent: acts and instructions establish formal rules; workshop and consultation materials reconstruct the development of policy ideas; institutional plans and evaluation documents show how those rules were operationalised. The comparison follows five dimensions across the successive models: the object of assessment, evidential basis, mode of judgment, decision authority and consequences of the judgment. The 2025 draft, response and final documents are used here to reconstruct the procedural design and the existence of a response stage; criterion-level analysis of response content and grade revisions is reserved for a separate empirical study. A complete longitudinal dataset of programme scores and funding changes before ZZrID is not yet available, nor are the full National Institute of Chemistry evaluation report, the complete 2025 correspondence trail or the final 2026 evaluation corpus.

These gaps limit causal conclusions but do not prevent analysis of the documented institutional design.



Figure 1: Main stages in the development of research evaluation in Slovenia, 2004–2026.

Data access and author position. The author served as Director of ARIS from 2023 to 2025 and is currently affiliated with the Jožef Stefan Institute. All documents and data analysed in this study were obtained from publicly accessible sources or through procedures under the Slovenian Access to Public Information Act (ZDIJZ) [32]; therefore, the study's evidential basis does not depend on privileged access connected to the author's former position at ARIS or at JSI. That professional experience contributes to familiarity with how the Slovenian research-funding and evaluation system functions. Such institutional understanding is not exclusive knowledge and can be reconstructed from the legal and documentary framework cited in this article.

2 From Programme Continuity to Institutional Accountability

Before ZZrID, ARRS did not evaluate only projects. It also assessed research programmes, typically for six-year funding periods, under rules that included external review, scoring and pre-conciliation ranking [1, 3, 9]. The crucial difference was the function of assessment. Project calls were competitive selection mechanisms. Programme evaluation operated within a financial architecture in which an organisation's total programme funding would, as a rule, remain stable. New or expanded programmes therefore depended largely on funds released by reducing or terminating existing ones. A low score could (but not necessarily) directly threaten a group, while an excellent score did not guarantee a proportional gain. The rules consequently made cautious differentiation rational and gave ARRS limited legitimacy and redistributive capacity. The strongest presently supportable conclusion is therefore not that nothing changed, but that the system had a pronounced normative bias towards continuity. Measuring its full empirical extent still requires complete historical score and funding data.

A domestic qualitative precedent nevertheless existed. A February 2021 record describes an external evaluation of the National Institute of Chemistry using external experts, written unit material, a site visit, interviews and developmental recommendations that reportedly led to organisational changes [27]. The procedure was not a national funding competition and cannot be transferred directly, but it shows that qualitative institutional review aimed at real restructuring was possible before the national reform. The full evaluators' report and formal instructions are not in the present corpus.

ZZrID changed the underlying compact in 2021. Six-year stable-funding contracts granted recipients greater autonomy,

while Articles 28, 30 and 31 linked that autonomy to strategic objectives, indicators, programme evaluation by ERC domains and institutional self-evaluation; external institutional evaluation was added later [2]. Before the first contracts were signed, recipients prepared research-activity implementation plans for 2022–2027. These 54 plans constitute the first common institutional self-description of the system [28]. They combined bibliometrics, projects and income with staff development, infrastructure, knowledge transfer, open science and governance. Because definitions, periods and units differed, the indicators cannot legitimately be converted into a simple league table. They are more useful as evidence of what organisations themselves understood as quality at the start of stable funding.

3 The 2022 Formula and the Turn towards Responsible Assessment

The first attempt to link institutional quality to variable, stable funding was the formula in the 2022 General Act [4, 24]. Recipients were divided into five organisational groups, and up to 10 per cent of ISF and PSF was to be redistributed through four components: previous programme scores, ARRS project funding, foreign-source funding, and contract research funding. The December 2022 analysis [23] argued that the formula did not measure what it purported to measure. Project and A3 income reflect funding structure and acquisition capacity; they may contextualise the research environment but do not directly measure scientific excellence or societal impact. Simulations indicated a structural paradox: research-intensive universities and public institutes could lose, while organisations in which research was supplementary could gain from individual projects or contracts. The model also rewarded short-term and stochastic anomalies and reproduced historical advantages.

The critique did not reject quantitative evidence. It proposed a transitional model that used programme assessment as a short-term proxy for research quality, qualitative impact case studies, and evaluation of the institutional environment, with funding diversity treated only as contextual evidence. It also drew boundaries later central to the reform: researcher-level CV items cannot simply be aggregated into institutional quality; visibility and reputation are not equivalent to impact; teaching activity is not automatically research impact; and an income stream does not demonstrate external change.

At the same time, the European framework moved towards qualitative expert judgment and responsible, supporting use of indicators. The Council conclusions, CoARA, DORA, the Leiden Manifesto, UNESCO open-science principles and the European Charter for Researchers all contributed to this change [14–19]. In Slovenia, it became visible in the Open Science Regulation [7], ARIS participation in CoARA, and the 2024 General Act on Research Titles [8]. The latter recognises publications alongside data, software, methods, patents, mentorship, leadership, open science, knowledge transfer and societal engagement, while retaining quantitative thresholds and SICRIS/COBISS elements. It is therefore a hybrid rather than a complete break. Its interpretation also depends on documents and standards it references; these versions should be archived, especially changing online materials such as Biblio-A/Biblio-C.

The conceptual redesign was already explicit in the Jožef Stefan Institute workshop of June 2023 and the KOsRIS–RKRS–

ARIS consultation of October 2023 [25, 26]. Foreign examples, including the Dutch SEP and the UK REF [20, 21], encouraged fewer but more relevant indicators, peer review, site visits, strategic dialogue and separation of formative learning from summative allocation. The workshop distinguished programme evaluation, institutional self-evaluation, Article 28 negotiations, variable funding and internal programme management. A follow-up recommendation proposed a developmental pilot without financial consequences. Consultation participants broadly supported external validation of self-evaluation but raised concerns about ARIS's dual role as funder and evaluator, overlap with NAKVIS, organisational diversity and automatic conversion of judgment into funding.

4 The 2025 Proto-Evaluation and the Response Stage

The proto-evaluation conducted from January to June 2025 was the first common assessment of all 54 recipients. It used revised 2022–2027 plans and reports on achievements in 2022–2024, classified under scientific excellence, social and economic impact, and international involvement [5, 10, 29]. Allowing organisations to revise the original contractual plans was practically understandable because the 2022 documents had not been designed as comparable English-language assessment material. Methodologically, however, the exercise no longer directly tested fulfilment of the original 2022 commitments. The uniform A–D template provided a common structure but raised comparability questions across highly heterogeneous universities, public institutes, clinics and small specialised recipients.

The pilot was not entirely consequence-free, although the final redistribution was only 0.05 per cent of total ISF and PSF, approximately EUR 114,000 [9]. Its most sensitive procedural stage followed the initial assessments: organisations received draft reports and could submit responses before panels produced final reports [30, 31]. A response stage may legitimately correct factual mistakes, overlooked evidence submitted on time or procedural violations. If it permits new substantive evidence or renewed argument about professional judgment after the preliminary score is known, it becomes a form of reassessment. In competitive ARRS and European procedures, redress traditionally concerns process or manifest error rather than a new scientific judgment [3, 22]. Institutional review may be more dialogic, but the applicable model and admissible grounds should be defined before scoring.

This article does not analyse which organisations obtained grade revisions or why. Those outcomes require criterion-level coding of the response content, the seriousness and evidentiary support of alleged errors, and the relation between response characteristics and final decisions; they are examined separately. For the longitudinal purpose here, the relevant institutional development is that the 2025 procedure formally inserted a response stage between draft and final judgment without fully resolving whether that stage was correction, appeal or continuation of the evaluative dialogue.

That distinction matters for the next cycle. A credible system must protect organisations against demonstrable error while avoiding a situation in which the meaning of a summative judgment can be renegotiated through unequal advocacy after

scores are known. The design questions are procedural rather than actor-specific: what information may be introduced after a preliminary assessment, who decides whether substantive reconsideration is justified, and how is every change documented and explained?

5 The 2026 Model and Required Safeguards

The 2026 framework is a substantive advance. Article 31 documentation requires an English institutional self-evaluation report, a Slovenian public summary and a continuous internal quality process [2, 11–13]. Scientific excellence is supported by a limited selection of outputs assessed for originality, contribution, rigour, reliability, transparency and reproducibility; journal impact factor and publisher prestige are excluded as direct evidence. Societal impact must identify the research basis, transfer pathway, beneficiary and demonstrable external effect. Dissemination, media presence, a patent or collaboration alone are not impact. The institutional research environment covers strategy, careers and doctoral training, infrastructure, collaboration and funding diversity, internal quality, open science, equal opportunities, and ethics and integrity. A foreign panel and site visit should test whether institutional narrative corresponds to actual practice. The 2026 General Act links institutional review with later ERC-domain programme evaluation and funding [6].

The model now places financial data in their proper context and explicitly allows organisations to consider improvement, transformation, merger, creation or termination of programmes. This addresses the old status quo. Yet the first cycle lacks prior ERC-domain programme reports, so the self-evaluation narrative is the central substantive input. This places a premium on clear institutional evidence and on panels' ability to contextualise it consistently across organisations. Not all full self-evaluation reports are public because the process is ongoing; no outcome claims are therefore justified.

Five safeguards are essential. First, the criteria, evidence rules and conversion methods must be finalised before submission. Second, formative dialogue must be separated from summative scoring. Third, the response framework must distinguish factual correction from substantive reassessment, define admissible evidence in advance, ensure equal procedural opportunities and preserve a traceable draft-response-final record. Fourth, financial consequences should remain limited until inter-panel consistency and disciplinary fairness have been independently reviewed. Fifth, indicators must remain contextual evidence, and the eventual meta-evaluation should examine not only rankings but whether the process leads to credible organisational decisions.

6 Longitudinal Change, Legitimacy and Comparability

The transition from 2022 to 2026 is not simply a move from numbers to narratives. Indicators remain present throughout, but their function changes. In the 2022 formula, selected numbers directly generated a funding result. In the 2022 institutional plans, indicators were self-selected descriptions of intended development. In the 2025 proto-evaluation, indicators and narratives were translated into three A–D grades. In 2026,

quantitative evidence is formally subordinated to qualitative expert judgment. This is methodologically more appropriate, yet also more demanding: panels must understand the institutional context, disciplines, research outputs, impact pathways, and organisational conditions, and explain why the evidence supports a particular judgment. Without such reasoning, a narrative score can be as opaque as a formula.

The reform can also be read as a sequence of three legitimacy problems. The old ARRS system possessed formal authority but insufficient professional legitimacy for major restructuring; programme assessment therefore coexisted with protected institutional continuity. The 2022 formula sought legitimacy through apparent objectivity. Yet the selection of variables embedded policy choices in the calculation: income became a proxy for impact, and previous funding success became a basis for future advantage. The 2025–2026 model seeks legitimacy through participation, self-evaluation, foreign expertise and dialogue. That is necessary because institutions hold much of the relevant evidence and must implement recommendations. It also creates a different potential vulnerability: qualitative systems depend heavily on panel reasoning, comparability and procedural consistency, including clear rules for how draft judgments can be corrected or substantively reconsidered.

Comparability is the central methodological difficulty. Formal equality does not necessarily produce substantive equality when the same template is applied to a comprehensive university, a public research institute, a clinic and a small specialised organisation. Absolute publication or project volume favours size, while progress against self-set objectives may reward modest targets. Complete individualisation, however, prevents meaningful comparison. The appropriate solution is a layered model: shared definitions of excellence, impact and institutional environment; disciplinary assessment of outputs; contextualisation by size, mission and organisational type; and explicit reasoning about how evidence was interpreted. The 2025 procedure illustrates why the unit of assessment must also be explicit: absolute institutional quality, progress since 2022, performance of stable-funded activities and the institution as a whole are related but not identical objects of assessment.

The concept of societal impact illustrates the improvement most clearly. Earlier documents often treated contract income, visibility, media activity, patents or collaboration as impact. These may be relevant activities or pathways, but they do not establish an external effect. The 2026 framework requires a demonstrable link from research, through transfer or engagement, to a change in technology, practice, policy, understanding, behaviour, or well-being. This protects the concept from becoming a miscellaneous collection of favourable institutional facts. The standard must nevertheless remain sensitive to time and discipline. Effects in language, culture, public health, infrastructure, and basic research may emerge slowly, indirectly, or collectively and cannot always be expressed in terms of immediate economic value. Independent corroboration should therefore be required without imposing a single commercial model of impact.

The same distinction is needed for responses to assessment. A site visit conducted before the panel completes its judgment can legitimately clarify evidence and support formative learning. A response submitted after the organisation has seen a preliminary score has a different procedural character. The

system should therefore specify in advance whether that stage is limited to correction, operates as an appeal, or forms part of continued dialogue, and what evidence is admissible in each case. The initial reasoning, the organisation's corrections, the panel's response and the exact basis of any change should form a complete audit trail. This would protect organisations from genuine error and reviewers from post hoc pressure while allowing later methodological evaluation of consistency among panels.

7 Conclusion

Slovenian research assessment has moved through three incomplete solutions. The old programme model delivered stability but restricted meaningful restructuring. The 2022 formula offered apparent objectivity while conflating past funding, internationality, quality and impact. The 2025–2026 qualitative model is conceptually stronger because it evaluates content, demonstrable impact and the institutional conditions for research, but it is also more dependent on procedural integrity. This article fills a gap by reconstructing, within a single longitudinal institutional framework, how the object, evidential basis, decision authority and consequences of Slovenian research assessment changed between 2004 and 2026.

The 2025 response stage exposed the need for clearer rules governing correction, clarification and substantive reconsideration; this article does not attribute particular revisions to institutional size, lobbying or other actor-specific causes. The 2026 pilot can overcome the previous status quo only if it protects reviewer independence, records the basis of changes and converts self-evaluation into real choices about programmes, careers, openness and institutional development. Final judgment must await the complete self-evaluation corpus, site-visit reports, institutional responses, final assessments and financial consequences. The logical continuation of the research is twofold: a separate criterion-level analysis of the 2025 response stage, followed after completion of the 2026 cycle by a meta-evaluation of inter-panel consistency, procedural comparability, organisational effects and funding consequences. The unresolved challenge is whether qualitative judgment can combine contextual sensitivity with transparent, comparable and procedurally equal treatment.

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From Draft Assessment to Final Grade: Institutional Responses, Organisational Size and Score Revision in Slovenia's 2025 Proto-Evaluation

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Abstract

Research-assessment reform increasingly relies on qualitative expert judgement, making the procedure between preliminary and final assessment part of the assessment methodology itself. Slovenia's 2025 proto-evaluation offers a case in which 25 of 54 recipients of stable research funding submitted Response Forms. Their three criterion-specific responses produced 75 organisation–criterion observations, coded for problem severity, evidentiary support, argumentative quality, requested remedy and organisational size. The response stage extended beyond factual correction: 24 organisations introduced information not clearly presented in the initial material, 21 challenged at least one panel judgement and 11 requested reconsideration or a different outcome. Yet only five standard grades changed, all from B to A. All five upgrades occurred in the largest size quartile, which represented 21 of 75 observations. The pattern remained when comparisons were restricted to major/fundamental problems and strong/very strong responses; at organisation level, membership in the largest size quartile was significantly associated with receiving at least one standard grade upgrade (Fisher's exact test, two-sided $p = .015$): three of seven SQ4 organisations received an upgrade, compared with none of the 18 organisations in SQ1–SQ3. The association does not necessarily establish a causal size effect or improper influence, but it shows why post-assessment systems must distinguish factual correction, substantive reconsideration and additional evidence, and why equal formal access to a response stage may not imply equal procedural capacity.

Keywords

research assessment; institutional evaluation; peer review; response procedure; organisational size; procedural fairness; stable funding; ARIS; Slovenia

1 Introduction and Evidential Basis

Research-assessment reforms increasingly replace mechanical indicator use with qualitative expert judgement [1–3]. This makes procedure more important, especially after an initial judgement has been reached. A response stage can correct factual errors, overlooked evidence or misapplied instructions, but it can

also function as an appeal or permit an organisation to strengthen its case after seeing the preliminary result. These functions are procedurally distinct, particularly when institutional evaluation may affect stable public research funding.

Slovenia's 2025 proto-evaluation assessed Scientific Excellence, Social and Economic Impact, and International Involvement on an A–D scale. Organisations could respond before final assessments were issued. The analysis therefore follows the sequence preliminary assessment → institutional response → final assessment and does not attempt to re-evaluate which grade each organisation objectively deserved. It asks: (RQ1) how the response stage was used; (RQ2) which characteristics of the organisations' response were associated with grade changes; and (RQ3) whether organisational size was associated with revision after comparing responses of similar seriousness and quality. If size differences disappear within comparable responses, they may simply reflect stronger objections; if they persist, procedural capacity becomes a relevant issue requiring further investigation.

Data access and author position. The author served as Director of ARIS from 2023 to 2025 and is currently affiliated with the Jožef Stefan Institute. All documents and data analysed in this study were obtained from publicly accessible sources or through procedures under the Slovenian Access to Public Information Act (ZDIJZ) [32]; therefore, the study's evidential basis does not depend on privileged access connected to the author's former position at ARIS. Professional experience contributes to familiarity with how the Slovenian research-funding and evaluation system functions. Such institutional understanding is not exclusive knowledge and can be reconstructed from the legal and documentary framework cited in this article.

2 Data and Method

2.1 Dataset and coding

The proto-evaluation covered 54 recipients of stable funding; 25 submitted Response Forms (46.3%), each addressing three criteria, yielding 75 organisation–criterion observations. Response Forms ranged from 3 to 15 pages (median 5; mean 5.48). For each observation, the preliminary grade, response, final grade, coded response characteristics and organisational size were linked. Responses were classified for claimed factual error or omission, misunderstanding or inconsistent application of instructions, additional explanation, information not clearly presented in the initial material, substantive challenge to professional judgement, and implicit or explicit request for a

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different outcome. “New information” denotes material introduced or substantially developed in the Response Form; similarly, coding an alleged factual error does not prove that the panel erred.

Problem severity (E) was coded E0 (none), E1 (minor), E2 (material but limited), E3 (major) or E4 (fundamental). **Evidentiary support (V)** was V0 (asserted only), V1 (internally supported by a traceable reference) or V2 (independently verified against primary evaluation documents). At this stage, 16 observations are V0 and 59 are V1; none are V2 because systematic external verification has not yet been completed. **Response quality** was scored 0–10 across specificity, traceability, evidentiary support, analytical relevance and procedural discipline, grouped as weak (0–3), moderate (4–6), strong (7–8) and very strong (9–10). **Requested remedies (R)** ranged from R0 (no requested change) to R4 (annulment/repetition). **Outcomes (O)** were O0 (unchanged), O+ (standard grade increased) and ON (normalisation of non-standard notation). The two FIŠ B/A normalization of non-standard notation cases are therefore ON, not O+. They also resolved one to final grade A and the other to B, not changing the summative final grade.

2.2 Organisational size and analytical strategy

Organisational size (S) was approximated by 2025 employee headcount from public organisational and annual-report sources. The 25 respondents employed about 24,504 persons. Because sources are not fully harmonised, size is treated as a rank-based category rather than a precise continuous measure. Organisations were divided into four approximately equal Size Quartiles (SQ1–SQ4), shown in Table 1. The terms small, medium and large are deliberately avoided because the absolute range, especially within SQ4, is substantial; the quartiles describe relative position in this sample, not a universal organisational classification. Each organisation contributes three observations, giving 18 observations in SQ1–SQ3 and 21 in SQ4; SQ4 therefore represents 28.0% of the criterion-level sample.

Table 1: Organisational size quartiles

SQ	Range	RO	Mean	Organisations
SQ1	9–25	6	16.3	IDSA/IRSA 9; CAMTP 10; IRRIS 12; ZRS Bistra 20; Peace Inst. 22; Criminology 25
SQ2	26–117	6	52.3	IER 26; INV 26; IMFM 45; FIŠ 49; IHPS 51; ZRS Koper 117
SQ3	201–603	6	357.0	NIB 201; UNG 231; KIS 254; ZRC SAZU 410; NIC 443; NIJZ 603
SQ4	705–8,697	7	3,135.7	UP 705; NLZOH 737; IJS 1,120; Oncology 1,410; UM 2,012; UL 7,269; UKC LJ 8,697

Only five standard O+ outcomes occurred, making conventional multivariable logistic regression unstable and vulnerable to separation. The analysis therefore uses descriptive cross-tabulation, comparisons within similar severity/quality groups, organisation-level robustness checks and Fisher’s exact test. Criterion-level results are descriptive because three observations belong to each organisation; the exact test is conducted at organisation level. The central robustness question is whether the size pattern persists within E3/E4 and strong/very strong responses.

Table 2: Standard O+ cases

Organisation / criterion	Rev.	E	Q	R
IJS – Excellence	B→A	E3	8	R0
IJS – Impact	B→A	E3	8	R0
UL – Excellence	B→A	E4	9	R4
UL – Impact	B→A	E4	9	R4
UM – Excellence	B→A	E4	9	R3

3 Results

3.1 Use of the response stage and basic conditions for revision

The response stage was used for overlapping purposes. All 25 organisations added explanation; 23 identified at least one claimed factual error, omission, or incorrect interpretation; 15 alleged misunderstanding or inconsistent application of instructions; 24 introduced information not clearly presented initially; 21 challenged at least one professional judgement; and 11 requested reconsideration, a higher grade, or repetition. At criterion level, additional explanation occurred in 70/75 observations (93.3%), new information in 64/75 (85.3%) and substantive challenge in 58/75 (77.3%). The process therefore functioned as correction, clarification, supplementation and substantive reconsideration, not only as factual-error correction.

Table 3: Severity (E) distribution and grade upgrades

E	n	Share	O+	Rate
E0	14	18.7%	0	0%
E1	4	5.3%	0	0%
E2	20	26.7%	0	0%
E3	28	37.3%	2	7.1%
E4	9	12.0%	3	33.3%
Total	75	100%	5	6.7%

Table 4: Response quality and grade upgrades

Quality	n	O+	Rate
Weak 0–3	5	0	0%
Moderate 4–6	10	0	0%
Strong 7–8	30	2	6.7%
Very strong 9–10	30	3	10.0%
Total	75	5	6.7%

All five upgrades followed E3/E4 and strong/very strong responses (Table 3), but these characteristics were not sufficient: only 5/37 E3–E4 observations (13.5%) (Table 3) and 5/60 strong/very strong observations (8.3%) (Table 4) produced O+.

3.2 Standard upgrades and organisational size

Of 75 observations, 68 were unchanged, five received a standard upward revision, and two were ON normalisations. All five standard revisions were B→A; three concerned Scientific Excellence and two Social and Economic Impact, with none for International Involvement (Table 2).

The upgraded observations came from Jožef Stefan Institute (IJS) (1,120 employees; two O+), University of Ljubljana (UL) (7,269; two O+) and University of Maribor (UM) (2,012; one O+). Their mean organisational size was 3,758 employees, compared with 980.16 across all observations. More importantly, every O+ occurred in SQ4 (Table 5): the quartile contained 21/75 observations (28%) but 5/5 upgrades, while SQ1–SQ3 contained 54 observations and no O+.

Among the five largest organisations in the analysed sample—the only five with more than 1,000 employees, namely UKC Ljubljana (1st), UL (2nd), UM (3rd), the Institute of Oncology Ljubljana (4th), and IJS (5th)—standard grade upgrades were observed for the 2nd-, 3rd-, and 5th-largest organisations, whereas the 1st- and 4th-largest organisations, both healthcare institutions, received no standard grade upgrade.

Table 5: Grade upgrades by size quartile

SQ	RO	Obs.	O+	Rate
SQ1	6	18	0	0%
SQ2	6	18	0	0%
SQ3	6	18	0	0%
SQ4	7	21	5	23.8%
Total	25	75	5	6.7%

3.3 Robustness across severity, quality and evidentiary support

The size pattern remains substantively comparable. For E3, SQ4 contained 2 upgrades out of 8 observations versus 0 upgrades out of 20 observations in SQ1–SQ3; for E4, the comparison was 3/4 in SQ4 versus 0/5 in SQ1–SQ3. Combined, 5/12 E3–E4 observations in SQ4 were upgraded versus 0/25 outside SQ4 (Table 6). The mean size of all E4 observations was 2,875.33 employees, compared with 5,516.67 for the three upgraded E4s.

Table 6: Severity categories by size quartile

E	SQ1	SQ2	SQ3	SQ4	N	O+1–3	O+4
E0	5	5	2	2	14	0	0
E1	1	0	1	2	4	0	0
E2	3	5	7	5	20	0	0
E3	9	4	7	8	28	0	2
E4	0	4	1	4	9	0	3

Quality shows the same pattern (Table 7). Among strong responses, SQ4 had 2/11 O+ versus 0/19 outside; among very strong responses, 3/8 versus 0/22. Thus, the lower three quartiles contained almost three times as many very strong observations as SQ4, yet none was upgraded. Strong and very strong responses combined yielded 5/19 O+ in SQ4 and 0/41 elsewhere. Mean size across all very strong responses was 1,373.90 employees, compared with 5,516.67 for the three O+ very strong responses.

Table 7: Response-quality categories by size quartile

Q	SQ1	SQ2	SQ3	SQ4	N	O+1–3	O+4
0–3	1	2	2	0	5	0	0
4–6	4	3	1	2	10	0	0
7–8	5	8	6	11	30	0	2
9–10	8	5	9	8	30	0	3

All O+ observations were V1 (Table 8). Within V1, SQ4 contained 15 observations and all five upgrades; the other quartiles contained 44 internally supported observations and no O+. Mean size was 1,156.88 employees across V1 and 3,758 among upgraded V1 cases. This is suggestive but not proof of differential treatment of equally valid errors: V1 means internally supported, not independently confirmed, and V2 remains unpopulated. A stronger future test would isolate independently verified E3/E4 claims.

Table 8: Evidentiary support and organisational size

V	n	Mean	SQ1	SQ2	SQ3	SQ4	O+
V0	16	328.50	2	6	2	6	0
V1	59	1,156.88	16	12	16	15	5
V2	0	—	0	0	0	0	0

Table 9 consolidates the same result: upgrades occurred only after serious, high-quality, and internally supported responses, but such responses were common outside SQ4 as well; nevertheless within each category, every observed upgrade remained in SQ4.

Table 9: Combined size profile across E, V and Q

Ind.	N	Mean	SQ1/2/3/4	O+	Mean O+	O+ SQ
All	75	980.16	18/18/18/21	5	3,758.00	SQ4:5
E0	14	155.21	5/5/2/2	0	—	—
E1	4	860.75	1/0/1/2	0	—	—
E2	20	790.15	3/5/7/5	0	—	—
E3	28	936.25	9/4/7/8	2	1,120.00	SQ4:2
E4	9	2,875.33	0/4/1/4	3	5,516.67	SQ4:3
V0	16	328.50	2/6/2/6	0	—	—
V1	59	1,156.88	16/12/16/15	5	3,758.00	SQ4:5
Q0–3	5	103.20	1/2/2/0	0	—	—
Q4–6	10	226.00	4/3/1/2	0	—	—
Q7–8	30	983.97	5/8/6/11	2	1,120.00	SQ4:2
Q9–10	30	1,373.90	8/5/9/8	3	5,516.67	SQ4:3

3.4 Organisation-level analysis and alternative simple explanations

At organisation level, three of seven SQ4 organisations received at least one standard upgrade and none of 18 organisations in SQ1–SQ3 did so (Table 10); Fisher's exact two-sided $p = 0.015$. Restricting the comparison to organisations with at least one E3/E4 response gives 3/6 in SQ4 versus 0/13 outside. With only three upgraded organisations, this is not proof of a causal size effect, but the revisions are clearly concentrated rather than dispersed across respondents.

Table 10: Organisation-level standard upgrades by size group

Size	≥1 O+	No O+
SQ4	3	4
SQ1–3	0	18

Neither an explicit request nor response length explains the pattern on its own. Two IJS grades changed despite R0, while other E3/E4 and strong/very strong responses explicitly sought reconsideration or a higher grade without success. At organisation level, 2/11 organisations that made an R1–R4 request received an upgrade, compared with 1/14 without such a request. The three receiving standard O+ submitted 4-, 4-, and 15-page Response Forms (median 4), compared with a median of 5 pages among organisations without standard upgrades.

4 Discussion

The response stage was substantively consequential and went beyond narrow factual-error correction. Procedurally, it combined three possible models: correction of the record, substantive appeal or reconsideration, and dialogic continuation of the evaluation. Any of these may be legitimate, especially in a proto-evaluation, but the applicable model should be defined in advance. If the purpose is error correction, the admissible intervention should focus on the record already before the panel. If substantive appeal is intended, the grounds for appeal and the authority deciding it should be specified. If the process is deliberately dialogic, reconsideration after institutional feedback is part of the evaluation model itself; in that case, organisations' capacity to participate effectively becomes a methodological variable rather than a purely administrative detail.

The results also show that seriousness and response quality explain only part of revision. No E0–E2 or weak/moderate response produced O+, so the panels did not revise grades indiscriminately. Yet 32 other E3/E4 observations and 55 other strong/very strong responses remained unchanged. Outside SQ4 alone, 20 E3, 5 E4, 19 strong, 22 very strong, and 44 V1 observations remained unchanged. Successful responses were therefore serious and well argued, but seriousness and quality were not sufficient conditions. The relevant empirical question is why only a subset of such responses resulted in revision. Organisational size is the strongest observable differentiator in this dataset: SQ4 contained 28% of observations but 100% of O+, and the concentration persisted within comparable severity and quality groups. This does not make size an explanation, but it also means size cannot be dismissed merely because the upgraded responses were substantively strong.

This association does not establish why revision occurred. Four explanations remain compatible with the evidence. First, large universities and multidisciplinary institutes may be intrinsically harder to represent through a uniform institutional template, making consequential preliminary misunderstandings

more likely. Second, E3/E4 are analytical categories rather than perfectly homogeneous errors; two fundamental objections may differ in how directly they demonstrate that a preliminary grade is untenable. Third, panels may differ in interpretation, internal deliberation or willingness to revise. Fourth, larger organisations may have greater administrative, analytical, managerial, legal and disciplinary capacity to reconstruct the assessment record and formulate an effective response. The last mechanism requires no lobbying or preferential treatment. It is a procedural-equity issue. Giving every organisation the same form and deadline establishes formal equality, but a large university may be able to mobilise several specialist units while a small institute may rely on a few individuals. If responses are limited to demonstrable factual corrections, such differences may matter relatively little; if the response can reopen qualitative judgement, differences in advocacy and analytical capacity can become part of the assessment process itself.

5 Implications for Future Evaluation Design

Future procedures should make the response function explicit. Each response point should be classified as a factual error, overlooked evidence already submitted, procedural or instruction-related error, disagreement with expert interpretation, or genuinely new information. The rules should state in advance which categories may justify amendment of a grade. Evidence that existed in the original evaluation record should be distinguished from material introduced only after the preliminary result became known. Where a grade changes, the final report should identify which objection was accepted and why it justified revision; this would make legitimate correction visible rather than leaving the reason for change implicit. If substantive appeal against professional judgement is permitted, consideration by an independent reviewer or differently constituted body may provide a clearer safeguard than unrestricted reopening by the same panel. Structured limits on the form and scope of responses may also reduce advantages arising solely from institutional resources. Finally, the complete audit trail—original submission → preliminary assessment → institutional response → disposition of each objection → final assessment—should be preserved. Such documentation would allow later testing of consistency, protect both evaluated organisations and evaluators, and help distinguish correction of an assessment from re-argument of the case after the first judgement is known.

6 Limitations

The analysis concerns the 25 organisations that submitted Response Forms, not all 54 organisations in the proto-evaluation; it therefore analyses variation within the response stage rather than determinants of participation in it. Only five standard upgrades occurred, limiting statistical power and precluding strong multivariable causal modelling. Criterion-level observations are clustered within organisations, so criterion-level comparisons are descriptive, and the exact test is conducted at the organisation level. V2 remains unpopulated because claims have not yet been systematically checked against all original plans/reports, ARIS instructions and draft reports; the analysis can therefore identify internally supported allegations but not prove that apparently comparable E3/E4 objections were equally valid. Employee counts come from several public sources, are not perfectly harmonised and produce a broad SQ4 range (705–

8,697 employees), so quartiles are rank-based rather than precise measures of FTE research capacity or homogeneous organisational types. Panel-specific revision propensity has not been modelled and remains an important alternative explanation. Finally, the documentary dataset does not capture possible communications outside the formal Response Forms, for example separate meetings of the largest organisations with the responsible Ministry or ARIS. Based on the current dataset, thus lobbying or improper influence cannot be inferred with substance

7 Conclusion

Slovenia's 2025 proto-evaluation shows that the transition from preliminary to final assessment is itself part of research-assessment methodology. Response Forms were used widely for clarification, supplementation and substantive challenge, but only five of 75 standard grades changed, all B→A. All five followed serious and well-argued responses, indicating that substantive grounds mattered; however, comparable responses were widespread and usually did not produce revision. The strongest additional pattern was organisational size: SQ4 represented seven of 25 organisations and 21 of 75 observations, but all five standard upgrades; 3/7 SQ4 organisations received at least one upgrade versus 0/18 elsewhere. Notably, among the five organisations with more than 1,000 employees—the only five above this threshold in the sample—the three non-healthcare organisations, the University of Ljubljana, the University of Maribor and the Jožef Stefan Institute, received standard grade upgrades, whereas the two healthcare institutions, UKC Ljubljana and the Institute of Oncology Ljubljana, did not. These three were also the three largest non-healthcare organisations in the sample. The concentration of institutions among the SQ4 organisations receiving upgraded grades remained for E3/E4 observations (5/12 vs 0/25), strong/very strong responses (5/19 vs 0/41), and very strong responses alone (3/8 vs 0/22), even though substantially more very strong observations occurred outside SQ4 than inside it. These findings do not establish a causal size effect or improper influence, and alternative explanations remain. They do establish that organisational size is associated with the observed revision pattern in a way that cannot be dismissed simply by noting that successful responses were serious or well argued. A credible qualitative assessment system must therefore distinguish transparently between correcting an error, reconsidering professional judgement and strengthening the institutional case after a preliminary result is known. It must also recognise that equal formal access to a response stage may not create equal effective procedural capacity.

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One Agency, Many Principals: Centralisation and Fragmentation of Research and Innovation Support in Slovenia

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Abstract

Slovenia has concentrated the implementation of research and innovation measures within the Slovenian Research and Innovation Agency (ARIS), while policy objectives and funding remain distributed across several ministries. This paper examines whether institutional centralisation has also reduced fragmentation of the funding portfolio. We analyse positive budget items in ARRS/ARIS financial plans for 2016, 2021 and 2026 using portfolio size, the share of the five largest items, the Herfindahl-Hirschman Index (HHI), its inverse effective number, small-item indicators, and comparable-family HHI robustness check. The coded portfolio increased from EUR 150.2 million to EUR 441.9 million, while positive items increased from 22 to 44 and HHI declined from 0.216 to 0.125. The comparable-family HHI also declined from 0.538 to 0.394. The stable research core grew in absolute value but declined as a portfolio share, alongside a growing tail of smaller measures. The study identifies portfolio-level governance as an important complement to centralised implementation.

Keywords

research and innovation policy, fragmentation, portfolio governance, ARIS, HHI, Slovenia

1 Introduction: one agency does not necessarily mean one system

Slovenia has made an important institutional change in the governance of research and innovation funding. The adoption of the Scientific Research and Innovation Activities Act in 2022 and the transformation of the Slovenian Research Agency (ARRS) into the Slovenian Research and Innovation Agency (ARIS) in 2023 brought research and innovation implementation increasingly under one agency within a more coherent institutional framework.

The financial plans for 2016, 2021 and 2026 show the scale of this transformation. The coded ARRS/ARIS portfolio increased substantially over the period, while its composition also became more diverse. The 2026 portfolio includes stable research funding, competitive research instruments and a growing number of innovation measures implemented for the Ministry responsible for science, the Ministry responsible for economy, and the Ministry responsible for digital transformation.

Centralisation of implementation, however, does not necessarily mean centralisation of policy. ARIS may administer calls, perform evaluations, monitor projects and process payments, while ministries continue to determine objectives, funding envelopes and thematic priorities. The result can therefore be described as one agency with multiple principals.

This distinction matters because a growing policy portfolio can become difficult to manage even when implementation is centralised. In knowledge-based economies, competitiveness depends not only on generating knowledge but also on transferring and valorising it. Policy instruments should therefore be considered as parts of a broader policy mix, where their objectives and interactions are assessed at portfolio level. New instruments should be assessed against the existing portfolio and justified by demonstrable added value to the development of the innovation ecosystem.

The paper therefore asks whether the centralisation of implementation has also reduced fragmentation of the funding portfolio. It examines three questions:

- (1) how have portfolio size and budget concentration changed;
- (2) how has the relationship between the stable research core and smaller measures developed; and
- (3) what do these changes imply for governance of a system in which several ministries retain substantive policy responsibility?

2 Conceptual framework and method

Fragmentation can occur at different levels of a funding system. A funding family may contain several instruments, an instrument may generate several calls, and calls may contain separate lots or themes. Aggregating measures into broad funding families may therefore conceal operational complexity, while simply counting calls may overstate fragmentation where repeated calls implement the same instrument. This study consequently focuses on the level at which funding is recorded as a distinct positive budget item in the official ARRS/ARIS financial plans. This level is relevant to portfolio governance because separately funded measures represent distinct components that the agency must plan and

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administer and may entail separate calls, eligibility conditions, evaluation procedures, contracting and monitoring requirements, thereby generating administrative and coordination demands for the implementing agency and additional complexity for applicants.

The dataset was constructed from the official ARRS/ARIS financial plans and available reports for 2016, 2021 and 2026 [1]. Secondary data were processed in five steps: (1) the official financial plans and available annual reports for the three reference years were collected; (2) separately identifiable positive budget items were extracted; (3) aggregate totals, control rows and zero-value items were excluded; (4) the remaining items were classified by function and stable-core status; and (5) portfolio totals, top-five shares, HHI, 1/HHI and sub-one-per-cent indicators were calculated for each year. The same coding rule was applied to all three reference years: each separately identifiable positive budget item was coded as one item, while aggregate totals, control rows and items without a positive value were excluded. The resulting dataset contains 22 positive items in 2016, 24 in 2021 and 44 in 2026. The increase in 2026 is largely associated with the addition of innovation measures, although differences in the aggregation of the source documents across years cannot be fully excluded. All 22 items in 2016 and all 24 items in 2021 belong to the research portfolio, whereas the 2026 portfolio contains 28 research and 16 innovation items. Thus, 16 of the net increase of 20 items between 2021 and 2026 is associated with the addition of innovation measures to the ARIS portfolio.

Budget-item-level coding was retained because the analysis aims not only to identify broad policy families but also to capture the operational structure of the portfolio administered by the agency. Aggregating separately funded measures into broader funding families would reduce the measured number of items by construction and could conceal an important dimension of portfolio complexity. The analysis nevertheless distinguishes conceptually between funding family, instrument, call round, and lot or theme and does not assume that every separately recorded budget item constitutes a distinct policy instrument.

Fragmentation is considered in four dimensions: budgetary, programmatic, institutional and procedural. The available dataset provides the strongest evidence on budgetary fragmentation and allows a partial assessment of programmatic fragmentation, while institutional and procedural fragmentation require further analysis of individual measures. The present analysis should therefore be interpreted primarily as an assessment of the size, composition and concentration of the portfolio at the budget-item level.

For each reference year, the analysis calculates the total value and number of positive budget items, the share of the five largest items, the Herfindahl-Hirschman Index (HHI), its inverse effective number, and the number and combined value of items representing less than one per cent of the annual portfolio. The HHI is calculated as the sum of squared budget shares of all positively coded items [2]. Its inverse, 1/HHI, represents the effective number of equal-sized items producing the observed concentration [3]. Both indicators are used descriptively rather than as normative measures of an optimal portfolio. Because the unit of analysis is the budget item rather than the policy instrument, the effective number should not be interpreted as the number of distinct policy instruments.

To test whether the observed trend could result from differences in coding granularity, all items were additionally regrouped into the same seven comparable functional funding families for all three years: stable institutional and programme funding, competitive research and targeted programmes, researcher development, research equipment, scientific communication and support, international cooperation and mobility, and innovation measures. HHI was then recalculated at this common level of aggregation.

As a supplementary check, funding was also grouped into four non-overlapping development-stage categories (TRL 0, TRL 1–3, TRL 4–6 and TRL 7–9); measures spanning several categories were allocated proportionally across the TRL levels covered.

Finally, the analysis distinguishes a functionally defined stable research core from the remaining portfolio. The stable core comprises institutional and infrastructure funding, research programmes and young-researcher funding in 2016 and 2021 and their corresponding stable-funding components in 2026. Values are nominal and have not been adjusted for inflation.

Table 1. Indicators of portfolio concentration (a) and stable core and small-items (b).

a. Portfolio concentration indicators

Year	Portfolio EUR m	Positive items	Top 5 share	HHI	1/HHI
2016	150.2	22	83.3%	0.216	4.64
2021	236.0	24	78.4%	0.175	5.72
2026	441.9	44	68.4%	0.125	8.01

b. Stable core and small-item indicators

Year	Stable core EUR m	Stable core share	Small items	Small EUR m	Small share
2016	105.4	70.2%	12	7.6	5.0%
2021	152.6	64.7%	12	6.5	2.7%
2026	247.3	56.0%	29	33.9	7.7%

Note: Stable core is defined functionally and includes institutional and infrastructure funding, research programmes and young-researcher funding in 2016 and 2021, and the corresponding stable-funding components in 2026. Positive items are individual budget items with a value greater than zero; aggregate totals and control rows are excluded. Small items are positive coded items representing less than 1% of the annual coded portfolio. HHI and 1/HHI are calculated at the coded budget-item level and are sensitive to the level of aggregation.

3 Results

3.1 A substantially larger portfolio

The coded portfolio increased from EUR 150.2 million in 2016 to EUR 236.0 million in 2021 and EUR 441.9 million in 2026. The increase was therefore 57.1% between 2016 and 2021, 87.3% between 2021 and 2026, and 194.2% over the full period (Figure 1; Table 1a).

The increase in funding was accompanied by a much larger number of positive coded items. Their number increased only slightly, from 22 in 2016 to 24 in 2021, but reached 44 in 2026. At the same time, the share of the five largest items declined from 83.3% to 78.4% in 2021 and 68.4% in 2026 (Figure 2; Table 1a).

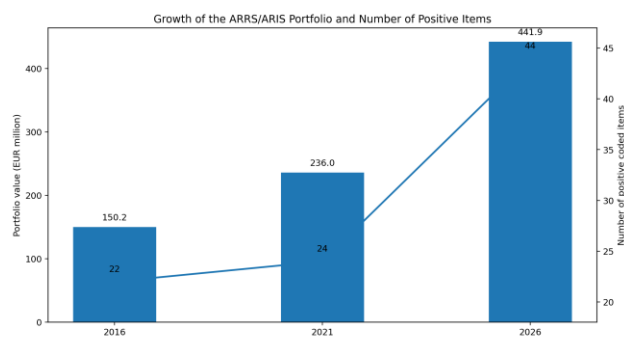


Figure 1: Growth of the coded portfolio and the number of positive item-level entries. Source: Authors' analysis of ARRS/ARIS financial plans 2016, 2021 and 2026.

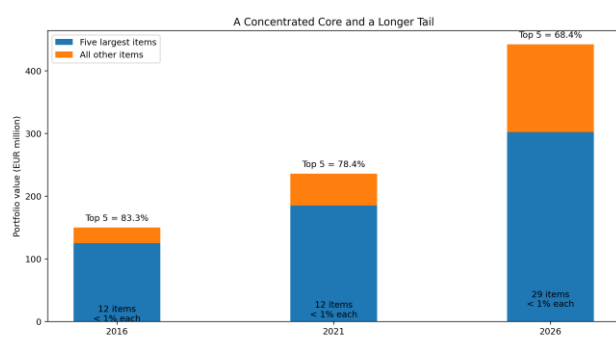


Figure 2: The five largest items and all other items, with the number of sub-one-per-cent entries. Source: Authors' analysis of ARRS/ARIS financial plans 2016, 2021 and 2026.

3.2 Lower concentration and a growing long tail

The decline in concentration is also reflected in the HHI. It fell from 0.216 in 2016 to 0.175 in 2021 and 0.125 in 2026. The corresponding effective number of equal-sized items increased from 4.64 to 5.72 and 8.01 (Table 1a).

The effective number describes the concentration of budget shares among coded items and should not be interpreted as the number of distinct policy instruments.

The robustness check at the comparable-family level shows the same overall direction. HHI declined from 0.538 in 2016 to 0.479 in 2021 and 0.394 in 2026. The decline in item-level concentration is therefore not solely an artefact of the more detailed structure of the 2026 portfolio.

However, when the new innovation family is excluded, the research-only family-level HHI is 0.538 in 2016, 0.479 in 2021 and 0.513 in 2026. The research portfolio alone therefore does not show a continuous decline in concentration; much of the additional diversification in 2026 is associated with the addition of innovation funding.

However, the supplementary TRL-based analysis points in the same direction for broader functional coverage: HHI across TRL groups changed from 0.690 in 2016 and 0.681 in 2021 to 0.457 in 2026, indicating that although the 2026 portfolio distributes funding across a wider range of development stages, it becomes more fragmented.

The long tail provides additional evidence of this structural change. The number of items representing less than one per cent of the annual portfolio remained at 12 in 2016 and 2021 but

increased to 29 in 2026. Their combined value increased from EUR 7.6 million in 2016 and EUR 6.5 million in 2021 to EUR 33.9 million in 2026 (Figure 3; Table 1b). The small-item tail therefore expanded both in number and absolute value, although it represented only 7.7% of the 2026 portfolio.

3.3 The stable core grows, but the portfolio around it grows faster

The stable core increased from EUR 105.4 million in 2016 to EUR 152.6 million in 2021 and EUR 247.3 million in 2026. Its share nevertheless declined from 70.2% to 64.7% and 56.0%, respectively (Table 1b), while the number and value of small items increased in 2026 (Figure 3), a trend primarily linked to the introduction of innovation measures.

The main structural finding is therefore not a simple shift from concentration to fragmentation. Rather, the portfolio has developed a large and increasingly well-funded stable core alongside a growing set of smaller competitive, complementary and innovation-oriented measures. The robustness analysis further indicates that the pre-existing research portfolio remains relatively concentrated and that much of the structural diversification observed in 2026 is associated with the new innovation layer.

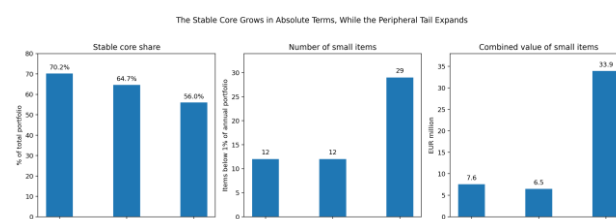


Figure 3: Stable-core share and the changing number and value of small items. Source: Authors' analysis of ARRS/ARIS financial plans 2016, 2021 and 2026.

This distinction is important for policy interpretation. A larger number of measures is not necessarily undesirable. Innovation policy may require different instruments for different beneficiaries, technology-readiness levels, regions or market failures. The question is whether each additional measure has a sufficiently distinct purpose and whether its benefits justify the additional administrative and coordination costs.

3.4 Centralised implementation, distributed policy ownership

The 2026 portfolio illustrates the multiple-principal structure. ARIS provides a common implementation capacity, while the substantive policy logic remains distributed among ministries. Measures may differ in funding source, target group, TRL range, regional requirements and legal basis, even though their administrative implementation is concentrated in the same agency.

This creates a distinction between administrative consolidation and portfolio consolidation. The former can improve professional implementation, evaluation capacity, monitoring and applicant services. The latter requires decisions about which objectives belong together, which instruments overlap and which measures should be adapted, merged or discontinued.

4 Discussion: centralisation without simplification

The results support the interpretation of the Slovenian system as centralised at the centre but increasingly diverse at the edge. ARIS has accumulated substantial implementation capacity, while the number and diversity of measures administered through it have increased. This interpretation is strongest at the budget-item level, where separately recorded items increased from 22 to 44 and concentration declined substantially. The comparable-family analysis and robustness checks confirm that the overall decline in concentration is mainly caused by fragmentation and only part can be explained by diversification linked to the expansion of ARIS into innovation funding, even though the research-only result shows that the change is driven to a considerable extent by the addition of the innovation portfolio.

The growing long tail should not automatically be regarded as policy failure. Small instruments may address specific gaps that cannot be covered efficiently by large programmes. However, each new measure creates fixed costs related to design, legal preparation, calls, evaluation, contracting, monitoring and reporting. These costs become particularly relevant when several instruments address similar beneficiaries or stages of the innovation process.

The policy challenge is therefore to govern the portfolio as a whole. A new measure should be assessed against existing instruments and justified by demonstrable additionality. At minimum, its introduction should answer four questions: What gap does it address? Which existing instruments address a similar problem? Why can the gap not be addressed by adapting an existing instrument? What additional benefit is expected relative to the administrative and financial cost?

The distinction between ARIS and other implementing bodies is also important. The present analysis does not establish that ARIS should absorb other agencies such as SPIRIT Slovenia. Nor does it demonstrate that organisational mergers would reduce fragmentation. The more immediate requirement is a common national portfolio view covering measures implemented by ARIS, SPIRIT Slovenia, the Slovenian Enterprise Fund, SID Bank and ministries directly.

A useful institutional comparison is provided by the Dutch Research Council (NWO), which presents its research funding through a relatively limited set of high-level funding lines, while allowing numerous programmes and calls underneath them [4, 5]. The relevance of this example is not that Slovenia should copy the Dutch system, but that new calls can be accommodated within stable funding families without necessarily creating new top-level policy architectures.

As much of the structural diversification observed in 2026 is associated with the addition of innovation funding, a logical next analytical step is to examine this part of the portfolio in greater technical and substantive detail. A companion study [6] analyses 16 ARIS innovation instruments in terms of their funding sources, objectives and beneficiaries, TRL coverage, balance between industrial research and experimental development, legal bases, implementation conditions and the participation of research and knowledge-dissemination organisations in research–industry knowledge transfer.

5 Policy implications and conclusion

The evidence suggests that Slovenia does not primarily need another institutional merger. It needs portfolio governance. Three principles appear particularly important.

First, Slovenia should establish a common public register of research and innovation instruments, identifying their funding family, objective, beneficiaries, TRL range, responsible ministry, implementing body, funding source, annual envelope and duration.

Second, a mandatory new-instrument test should require every new measure to demonstrate a specific gap, distinguish itself from existing instruments and show expected additionality.

Third, stable funding families should provide the basic architecture, while new themes, technologies or target groups should normally be introduced as modules within existing families rather than as entirely new schemes.

Such an approach would not necessarily reduce the number of calls. Its purpose would be to make the policy portfolio more coherent, transparent and governable. Temporary or overlapping measures could be reviewed, consolidated or allowed to expire, while genuinely distinct instruments could remain.

The central finding is therefore that Slovenia has achieved considerable institutional centralisation without equivalent portfolio simplification. Between 2016 and 2026, the coded portfolio almost tripled, the stable research core more than doubled in value, and the number of positive coded items doubled. At the same time, budget concentration declined and the long tail of small items expanded. The resulting structure is best described as a concentrated core with a long tail. The key policy question is no longer where to place another organisational responsibility, but how to ensure that all research and innovation measures are considered as parts of one national portfolio. Without such governance, individual measures may each be justified while the system as a whole becomes increasingly difficult to understand, coordinate and evaluate.

AI use statement: Artificial intelligence was used as a supporting tool throughout the manuscript for English-language editing, shortening and consolidation of the text, improvement of clarity and structure, and formatting and standardisation of references. It was additionally used to support the formulation and refinement of the Introduction, selected paragraphs of the Discussion, the Conclusion and the Abstract. AI was not used to develop the research methodology, collect or classify the data, perform the analyses or calculations, or produce the results, tables and figures, which are entirely the authors' original work.

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International Comparative Analysis of Intellectual Property Management: Policy Recommendations for Strengthening Slovenia's Innovation Ecosystem

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Abstract

Effective management of intellectual property (IP) and technology transfer is a key driver of innovation and knowledge valorisation. This paper compares IP management and technology transfer systems in Finland, Germany, Norway, and the United Kingdom to identify good practices relevant to Slovenia. The study combines quantitative analysis of IP and innovation indicators with qualitative analysis of institutional frameworks, knowledge transfer offices (KTOs) and technology transfer offices (TTOs), commercialisation policies, and national IP strategies. The findings show that successful systems integrate IP management into broader innovation policies and are supported by professionalised KTOs, strategic IP management, early-stage commercialisation support, strong university–industry collaboration, and targeted incentives. Examples include Cambridge Enterprise, Finland's integrated IP policy, Norway's strategic IP advisory services, and Germany's Fraunhofer model. For Slovenia, the quantitative findings indicate a weaker relative position in patent applications than in international trademark applications, while its position in EU design applications is mixed; the qualitative comparison identifies potential improvements in IP management within publicly funded R&D, KTO capacities, IP competencies and the alignment of knowledge valorisation with national innovation strategies.

Keywords: intellectual property management; technology transfer; knowledge transfer; knowledge valorisation; IP indicators; innovation policy

1 Introduction

Innovation performance depends not only on the generation of new knowledge, but also on the capacity to identify, protect, manage and translate that knowledge into economic and societal value. Intellectual property (IP) therefore plays a broader role than the legal protection of inventions, brands and designs: when strategically managed, intellectual assets can support research collaboration, knowledge and technology transfer, investment, and commercialisation of research results in terms of licensing, spin-outs etc. This perspective is increasingly reflected in European knowledge-valorisation policy, which emphasises the management of intellectual assets throughout the research and innovation process, including ownership, collaboration, open

science, licensing, spin-out creation and links to market uptake [11].

Universities and public research organisations occupy an important position in this process. The literature identifies technology and knowledge transfer offices (TTOs/KTOs) as key intermediaries between research organisations and industry, supporting activities such as invention assessment, IP protection, licensing, spin-out formation and access to external partners and funding [6]. Throughout this paper, KTO is used as an umbrella term encompassing both knowledge transfer offices and technology transfer offices, reflecting the broader scope of knowledge transfer. While knowledge transfer (KT) refers to the broad exchange of knowledge, expertise, and skills between organisations and individuals, technology transfer (TT) focuses on transferring and commercialising specific technologies, inventions, and intellectual property. The primary goal of the latter is the commercialisation of a specific invention. Collaborative research, contract research, academic engagement and wider university–industry relationships form complementary channels through which knowledge is transferred and commercially exploited [5]. However, countries differ considerably in how effectively these mechanisms are organised and embedded within their broader innovation systems. In some national contexts, TT is supported by highly professionalised KTOs, strong links between research organisations and industry, dedicated funding for early-stage commercialisation, and policy instruments that encourage strategic IP management. In others, these functions remain more fragmented or are less systematically integrated into research and innovation policy. Slovenia represents a particularly relevant case for such an analysis. Previous studies and policy assessments have identified persistent challenges in the commercialisation of publicly generated research, the capacity and institutional development of TT structures, and the effective use of IP by firms, particularly SMEs [4] [7] [8].

Against this background, this study compares Slovenia with Finland, Germany, Norway and the United Kingdom. The purpose of this study is not to identify a single model to be replicated in Slovenia, but to determine which institutional arrangements and policy instruments may provide transferable lessons for strengthening IP management, research

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commercialisation and TT in the Slovenian innovation ecosystem.

2 Methodology

This study employed a mixed-methods comparative approach, combining quantitative benchmarking of industrial property and innovation indicators with qualitative analysis of IP management and TT systems. Slovenia was used as the reference country and compared with four European countries – Finland, Germany, Norway and the United Kingdom – which were selected purposively rather than randomly, considering the presence of established IP strategies, examples of good practice in IP management and TT, and access to professional contacts who could provide additional insights into specific aspects of their systems. The purpose of the comparison was to identify practices that could provide relevant and transferable insights for strengthening the Slovenian innovation ecosystem.

The quantitative analysis was based on five groups of indicators: European patent applications, international patent applications filed under the Patent Cooperation Treaty (PCT), international trademark applications under the Madrid System, registered EU designs, and innovation performance measured through the Global Innovation Index (GII). Data were obtained from the European Patent Office (EPO) [12], WIPO PATENTSCOPE [13], WIPO Madrid Monitor [14], the European Union Intellectual Property Office (EUIPO) [15], and the Global Innovation Index dataset [16] used in the project. Population data were obtained from the World Bank Open Data database. The data were initially collected in September 2025 and subsequently checked and updated at the end of October 2025.

To account for substantial differences in country size, patent, PCT, trademark and design application counts were normalised by population and expressed as the number of applications per 10,000 inhabitants:

$$I_{c,t} = \frac{A_{c,t}}{P_{c,t}} \times 10.000$$

where $A_{c,t}$ denotes the number of applications in country c in year t , and $P_{c,t}$ represents the corresponding population. The analysis covered 2015–2024 for European patent and PCT applications, 2020–2024 for international trademark and EU design applications, and 2011–2024 for the Global Innovation Index. Descriptive calculations, data processing and graphical representations were performed using Microsoft Excel.

The quantitative benchmarking was complemented by a qualitative comparative analysis of national IP management and TT ecosystems. Publicly available national strategies, policy documents, institutional information, programme documentation, professional reports and other relevant sources were reviewed to examine the institutional, regulatory and support frameworks in each country.

Information obtained through the authors' professional and research contacts complemented the documentary sources and informed the comparative findings; more detailed country-level analyses will be presented in forthcoming project reports, as space constraints preclude their inclusion here. For the United

Kingdom, the analysis draws on preliminary findings from in-depth interviews conducted by Lamut and Hafner with Cambridge Enterprise staff in April 2026; a summary of the key findings was presented at a conference [2], while the detailed results have not yet been published. Good practices were subsequently identified through cross-country comparison, with particular attention to approaches supporting effective IP management, research commercialisation, KT and TT, and cooperation between research organisations and industry. Their relevance was assessed based on their potential applicability to the Slovenian research and innovation environment.

3 Results

This section presents the quantitative comparison of industrial property and innovation indicators, followed by a qualitative comparison of IP management and TT practices in the selected countries.

3.1 Quantitative comparison of industrial property and innovation indicators

The quantitative comparison revealed differences in Slovenia's relative position across the selected industrial property indicators. Slovenia recorded fewer European patent and PCT applications per 10,000 inhabitants than all four comparison countries throughout 2015–2024. Its relative position was stronger in international trademark applications, whereas the results for EU design applications were mixed.

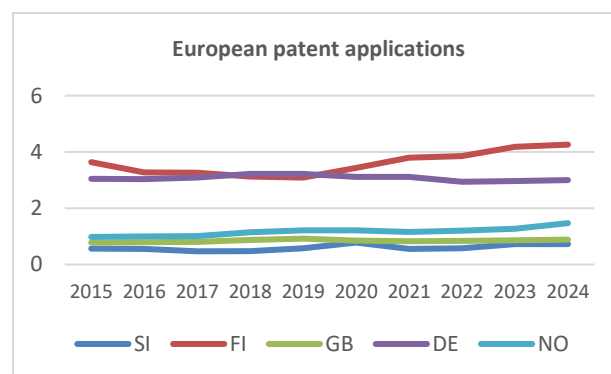


Figure 1: European patent applications

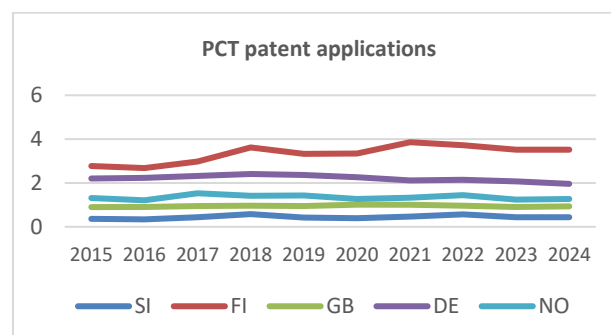


Figure 2: PCT patent applications

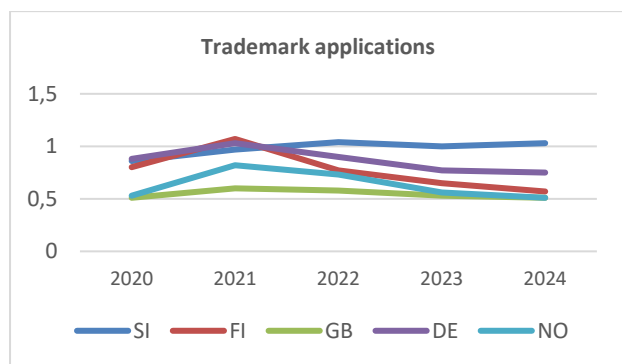


Figure 3: Trademark applications

Slovenia recorded the highest number of international trademark applications per 10,000 inhabitants among the selected countries in the final years of the period examined (Figure 3). In EU design applications, it remained below Germany and Finland, while its position relative to the United Kingdom and Norway was generally more favourable.

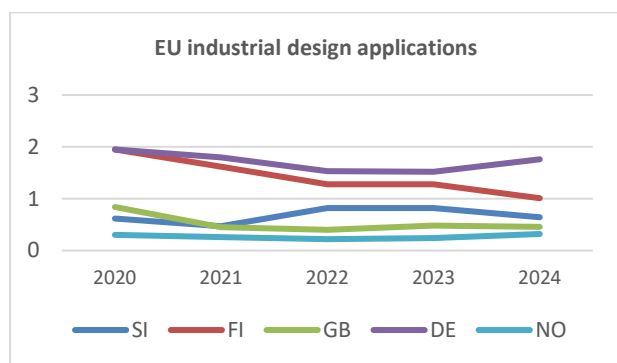


Figure 4: EU industrial design applications

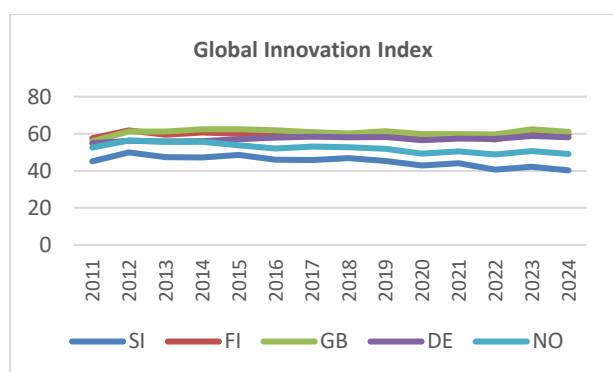


Figure 5: Global Innovation Index

3.2 Comparative analysis of IP management and KT/TT practices

The qualitative comparison showed that all four reference countries have developed and institutionally supported IP systems, including national IP offices, TT structures, innovation-support institutions and intermediary organisations. Differences occur primarily in the organisation and emphasis of institutional support and in the mechanisms through which research organisations are connected with industry. The United Kingdom is characterised by a developed university entrepreneurship and

TT ecosystem; Norway combines IP administration with substantial advisory and innovation-support functions; Finland closely integrates IP management with its broader innovation policy; while Germany is characterised by strong research–industry links and well-developed mechanisms for TT.

In the United Kingdom, IP is treated not only as a mechanism for legal protection but also as a strategic instrument for KT and business development. Universities and their KTOs play an important role in patenting, licensing and the creation of spin-out companies. The analysis identified Cambridge Enterprise [17] as a particularly developed example of this approach. Its activities extend from the identification and protection of research results to licensing and spin-out formation and include proof-of-concept funding, business-model support and access to investors. The organisation is closely integrated into the wider Cambridge innovation cluster, linking the university with companies, investors and support institutions. The UK Patent Box [9] represents an additional policy instrument encouraging the commercialisation of patented technologies.

The Norwegian system is distinguished by the broad role of the Norwegian Industrial Property Office (NIPO) [18], which functions not only as a registration authority but also as a source of information, training and guidance for companies and innovators. The system places considerable emphasis on strategic IP management and on activities preceding the filing of an application, including searches, preliminary assessments and Freedom to Operate analyses. These services may reduce the risks associated with unsuccessful applications, disputes and investment in technologies that interfere with existing rights. Strategic IP guidance for SMEs, pre-filing search and assessment services, digital access to IP information and guidance concerning employee inventions were identified as notable features of the Norwegian approach.

In Finland, IP management is strongly integrated into national innovation and industrial policy. IP is regarded as an element of economic value creation rather than exclusively as a legal mechanism of protection. Business Finland and Technical Research Centre of Finland (VTT) [10] play important intermediary roles between research and industry, linking technology development with the protection, management and commercialisation of intellectual assets. IP management is therefore incorporated throughout the innovation cycle, from research funding to market entry. Universities and research organisations are supported by developed TT structures, while the system also combines digitalised IP services with an approach that seeks to balance open science and the protection of commercially relevant research results.

The German model is characterised by a particularly strong connection between applied research and industry. This is most clearly represented by the Fraunhofer model, in which contract research for industry is combined with systematic protection and commercialisation of research results through patenting, licensing and spin-out creation [1, 3]. Fraunhofer also provides an environment for collaborative pre-competitive technology development, enabling companies to share development costs and risks. In parallel, the German Patent and Trade Mark Office

and the network of Patent Information Centres (Patentinformationszentren, PIZ) form the German network PIZnet [19] and provide information, advisory and patent-search services. Patent-information infrastructures, public IP databases, standardised approaches to TT and specialised support services were identified as additional relevant features of the German system.

Across the four countries, several recurring characteristics of effective IP and TT systems were identified. IP is generally treated as a strategic instrument linking research, industry and innovation policy rather than merely as a legal right. The analysed systems combine professional technology transfer structures, proactive management and commercialisation of IP, mechanisms supporting licensing and spin-out creation, and links with industry. Their institutional ecosystems are further complemented by advisory networks, innovation agencies, funding schemes, patent information services, and other intermediary organisations that facilitate access to the IP system.

4 Discussion and conclusions

The quantitative findings place Slovenia below the four comparison countries in European patent and PCT applications per capita, but show a stronger relative position in international trademark applications and a mixed position in EU design applications. These differences concern application activity within each protection system and should not be interpreted as direct evidence of stronger branding and design capabilities or weaker research-based innovation. Considered alongside the qualitative findings, they provide a basis for discussing how Slovenia could strengthen IP management and research commercialisation. The comparative analysis shows that effective systems embed IP management throughout the innovation cycle, linking research, public funding, industry collaboration, TT and commercialisation.

A first priority is the systematic integration of IP management into publicly funded research and innovation. IP strategy should be considered early in R&D projects, including ownership, protection and exploitation. Finland provides a relevant example, with IP considerations integrated from research planning to market entry and internationalisation.

Second, Slovenian KTOs should be further professionalised and their role extended beyond administrative IP management to licensing, spin-out development, business model support and investor relations. Cambridge Enterprise demonstrates the value of combining TT expertise with proof-of-concept funding and early-stage commercialisation support. Slovenian KTOs would therefore benefit from stronger professional capacities, early-stage funding mechanisms and closer links with investors.

Third, strategic IP support should be strengthened, particularly for SMEs and researchers. Norwegian practice highlights the value of pre-filing services such as prior-art searches, patent-landscape analysis, preliminary assessments and Freedom to Operate analysis. These could become a more systematic part of Slovenia's innovation-support infrastructure.

Slovenia should also build on its existing IP information and commercialisation infrastructure. The Slovenian national knowledge-transfer platform KTS (prenoszanja.si) could be further developed as a tool for technology commercialisation, supported by standardised contractual models, clearer ownership arrangements and stronger spin-out support. PATLIB and comparable structures could serve as regional IP competence centres providing patent searches, risk assessments, training and initial IP-strategy advice. While building on PATLIB centres as a foundation for Slovenia's SME support infrastructure is a promising approach, their currently limited role may require substantially greater funding, including dedicated resources for KTO staff, to enable effective support for SMEs. Their activities should be coordinated with KTOs, universities, chambers of commerce, the start-up ecosystem, URSIL and European IP institutions, with sustainable financing ensuring consistent regional support.

IP competencies and awareness also require more systematic attention. A national IP education programme for SMEs, start-ups and researchers, stronger public advisory services and greater integration of IP topics into education could help position IP as part of innovation management rather than as a specialist legal issue. National innovation agencies such as ARIS and SPIRIT could play a stronger intermediary role in connecting IP management, research and business development.

Finally, structural measures could be complemented by financial and fiscal incentives. The United Kingdom's Patent Box illustrates one approach to encouraging value creation from patented inventions, while proof-of-concept and other early-stage funding can help bridge the gap between research and market application. Rather than directly copying foreign instruments, Slovenia should identify the combination of funding, fiscal incentives and commercialisation support best suited to its innovation system.

Overall, Slovenia does not primarily lack formal IP protection mechanisms; the greater challenge is strengthening the ecosystem that transforms knowledge and technologies into protected and commercially valuable assets. Policy should focus on stronger integration of IP into innovation policy, professionalised KTOs, improved advisory infrastructure, closer links with investors, patent-oriented innovation, research–industry cooperation and more systematic commercialisation throughout the innovation cycle.

Acknowledgments

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Institutional Conditions for Knowledge Transfer in Slovenian Research Organisations

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Abstract

Knowledge transfer is one of the core missions of research organisations (ROs); however, its institutionalisation does not always keep pace with its strategic recognition. This paper presents selected findings from a broader assessment of knowledge transfer (KT) practices and processes in Slovenian ROs, focusing on differences related to institutional type, research orientation and institutional support mechanisms.

The analysis draws on survey indicators covering strategic recognition, dedicated support structures, internal procedures, staff incentives and awareness of intellectual property policies. The results indicate that KT is generally recognised as an important organisational function, while its formal institutionalisation remains uneven. Gaps are observed in the integration of KT into staff evaluation and promotion, the availability of specialised support capacities, systematic monitoring and researchers' awareness of relevant procedures.

The findings point to a gap between recognising KT as an organisational objective and systematically embedding it in institutional practice. They highlight the importance of strengthening organisational mechanisms that support KT while accounting for differences across research orientations and institutional types.

Keywords

Knowledge transfer; research organisations; institutionalisation; knowledge valorisation; institutional support

1 Introduction

Knowledge transfer (KT) is one of the core missions of research organisations (ROs), alongside research and, where relevant, education. ROs are increasingly expected not only to generate new knowledge but also to facilitate its use by industry, public institutions, policymakers and society. KT therefore encompasses a broad range of activities, including collaborative

and contract research, consultancy, stakeholder engagement, intellectual property (IP) management, licensing and spin-off entrepreneurship [1].

The diversity of these pathways is particularly relevant when comparing research orientations. Science, Technology, Engineering and Mathematics (STEM) organisations are more frequently associated with technological development, patenting, licensing and industrial collaboration, whereas social sciences and humanities (SSH) often transfer knowledge through policy advice, professional expertise, education, cultural activities and other forms of societal engagement [2]. Institutional support for KT therefore needs to accommodate different transfer pathways rather than rely on a single organisational model.

At the organisational level, strategic recognition of KT does not necessarily ensure its systematic implementation. Effective KT depends on governance, dedicated support, professional competencies, incentives and clear internal procedures [3–5]. Organisational characteristics and disciplinary specialisation also shape KT profiles and the way transfer functions are organised [6,7]. Dedicated knowledge or technology transfer offices can support IP management, legal and contractual issues, business development, training and external collaboration, but their presence alone does not guarantee an effective KT system [5]. KT may also remain weakly recognised in staff evaluation and career progression, despite the influence of formal and indirect incentives on researchers' external engagement [8].

Against this background, this paper presents selected findings from a broader assessment of KT practices and processes in Slovenian ROs. It focuses on four analytical themes: intellectual assets and predominant KT mechanisms, strategic recognition of KT, organisational support capacity, and the formal embedding of KT in organisational procedures and incentives. The central research question is: To what extent is the strategic recognition of KT in Slovenian research organisations accompanied by organisational structures, procedures and incentives that support its systematic implementation? Particular attention is given to differences between institutional types and research orientations. Rather than seeking a single optimal model, the analysis explores how institutional conditions for KT differ across Slovenian ROs and where gaps between strategic recognition and implementation remain. The added value of the study lies in providing an organisation-level comparison of how strategic recognition of KT relates to institutional support and formalisation across different types of Slovenian ROs and research orientations.

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The findings provide a basis for further quantitative and qualitative research and more differentiated KT support models.

2 Methodology

The analysis is based on a survey conducted among Slovenian ROs receiving stable research funding (54). A total of 34 ROs completed the questionnaire, while responses were not received from 20 organisations. The questionnaire was completed by organisational representatives familiar with KT activities and institutional procedures, including management, research-support and knowledge/technology-transfer personnel. Responses therefore represent organisational self-assessment rather than individual researchers' views. Data were collected between mid-July and the end of September 2025. For analytical purposes, organisations were grouped according to their institutional status into Public research organisations (PRO), higher-education organisations – academia (A) and “OTHER”, not falling into any of the above two categories.

Differences in research orientation, particularly between STEM and SSH, were also considered. As summarised in Table 1, an additional “ALL” category was used for organisations whose activities span both STEM and SSH fields. Missing responses were excluded from item-level and composite calculations; no values were imputed.

Table 1. Number of responding ROs by institutional status and research orientation (total number of ROs in the target population in parentheses).

Status / orientation	STEM	SSH	ALL	TOTAL
PRO	10 (10)	5 (5)	2 (2)	17 (17)
A	1 (2)	0 (1)	4 (6)	5 (9)
OTHER	5 (17)	7 (8)	0 (3)	12 (28)
TOTAL	16 (29)	12 (14)	6 (11)	34 (54)

The distribution of responses across institutional groups was uneven; therefore, the sample should not be considered statistically representative of all Slovenian ROs. Nevertheless, it provides broad institutional coverage and includes all PROs in the target population.

The full questionnaire contained 91 questions covering basic information, strategy and governance, organisational support and resources, external collaboration, intellectual property and commercialisation, monitoring and evaluation, and impact and culture. The broader assessment used these data as the basis for a SWOT analysis of KT in Slovenian research organisations.

The present paper focuses on a subset of these data, organised around four analytical themes:

1. **Intellectual assets and predominant KT mechanisms** – the main forms of intellectual assets and research outputs generated, together with the predominant pathways through which knowledge is transferred;
2. **Strategic recognition** – the extent to which KT is included in organisational strategies and research and innovation policies;

3. **Organisational support capacity** – the availability of dedicated knowledge-transfer structures, specialised support and access to relevant expertise;
4. **Formal institutionalisation** – the extent to which KT is embedded in internal procedures, intellectual property management, monitoring, staff evaluation and promotion.

For attitudinal statements, respondents assessed their organisation using a five-point scale (1 meant “strongly disagree” and 5 “strongly agree”). Group-level values reported below represent arithmetic mean scores. The analysis is exploratory and descriptive and aims to identify recurring patterns and differences across institutional types and research orientations. For descriptive comparison, selected items were also combined into three unweighted composite indicators: supportive KT culture, formal embedding and commercialisation mechanisms. Composite scores represent the arithmetic mean of the respective items.

3 Selected findings and discussion

The survey reveals substantial variation in KT practices across Slovenian ROs, particularly by institutional type and research orientation. STEM-oriented ROs more frequently generate patentable inventions, technologies, software and know-how, whereas SSH-oriented ROs predominantly produce copyright-protected works, digital content, databases and specialised knowledge. KT pathways also differ accordingly. SSH-oriented ROs primarily transfer knowledge through policy advice and policy documents, professional analyses, education, cultural activities, publications and engagement with public institutions and communities. STEM-oriented ROs more frequently report technological solutions, patents, licensing, industrial collaboration and spin-off activities. Organisations classified as ALL combine commercialisation-oriented activities with education and broader third-mission functions and are predominantly represented by higher-education organisations.

These differences suggest that institutional IP management and knowledge-transfer support should not rely solely on patent-oriented mechanisms but should also address copyright, software, know-how and other non-patent forms of intellectual assets.

Regarding strategic recognition, the survey indicates that KT has achieved a generally strong level of strategic recognition across Slovenian ROs (Table 2). Most organisations report a relatively clearly defined approach to KT and indicate that it is incorporated into broader research and innovation policies and organisational missions, with objectives generally aligned with national and European priorities. Integration into broader R&I policies and alignment with national and European priorities receive relatively high overall mean scores of 4.1 and 4.2, respectively. In contrast, regular review and updating of KT strategies receives the lowest overall score (3.2), suggesting that strategic recognition is more developed than the mechanisms supporting its continuous review and adaptation.

Among responding SSH-oriented OTHER organisations, annual strategy review scores 2.8, despite relatively high integration into R&I policy and alignment with national and European priorities.

Differences are also evident in the strategic orientation of KT. SSH-oriented organisations primarily emphasise societal,

cultural and policy-related impact, whereas STEM-oriented organisations show stronger links to technological development, industry collaboration, intellectual property, patents and spin-offs. Organisations classified as ALL, covering both STEM and SSH fields, generally display broader KT profiles combining commercialisation, educational activities and wider third-mission functions.

These findings indicate that strategic recognition of KT is relatively well established, but does not necessarily translate into equally developed structures, routines and support mechanisms for its systematic implementation. KT support should therefore be interpreted in relation to the specific transfer pathways and institutional settings of different research organisations. This is consistent with literature emphasising the importance of governance, organisational capabilities and institutional arrangements for effective KT.

Table 2. Strategic recognition and governance of knowledge transfer across Slovenian ROs. Values represent mean self-assessment scores on a five-point scale; n indicates the number of organisations in each subgroup. Missing responses were excluded from individual item calculations. Values for n = 1 are not presented.

Status & orientation	n	Clear KT strategy	KT in R&I policy	KT annual review	KT alignment with national/EU
PRO	17	3.8	4.0	3.3	4.2
ALL	2	4.0	4.5	3.5	4.5
SSH	5	3.8	4.0	3.4	4.2
STEM	10	3.7	3.9	3.1	4.1
ACADE-MIA	5	4.3	4.5	4.0	4.8
ALL	4	4.3	4.5	4.0	4.8
STEM	1	-	-	-	-
OTHER	12	3.7	4.1	2.9	3.9
SSH	7	3.7	4.5	2.8	4.3
STEM	5	3.8	3.5	3.0	3.3
Grand Total	34	3.8	4.1	3.2	4.2

While KT is relatively well recognised strategically, organisational capacity for implementation varies across institutional types and research orientations. Among the 34 responding organisations, 13 reported a dedicated knowledge or technology transfer office (Table 3). Where dedicated offices are absent, KT functions are typically performed by research-support personnel or directly by researchers.

The institutional type and disciplinary orientation of an organisation also appear to shape its support model. STEM-oriented PROs tend to show a higher degree of formalisation and specialisation, including internal intellectual property rules, dedicated bodies and processes related to employee inventions. Among responding higher-education organisations institutional support appears comparatively diversified, combining

operational knowledge-transfer functions with strategic bodies and other research-support structures.

By contrast, KT in SSH-oriented PROs and some OTHER organisations is more decentralised and often closely linked to individual research projects and researchers. Their research outputs are more frequently transferred through publications, policy input, education, cultural and digital content, and direct interaction with public institutions and other users. This pattern is consistent with previous studies showing that disciplinary specialisation affects both the channels through which knowledge is transferred and the organisational arrangements needed to support those channels [2,6].

Table 3. Number of ROs with dedicated knowledge/technology transfer offices against the received answers (total number of ROs in the target population in parentheses).

Status / Orientation	STEM	SSH	ALL	Total
PRO	6/10 (10)	0/5 (5)	1/2 (2)	7/17 (17)
A	0/1 (2)	0/0 (1)	4/4 (6)	4/5 (9)
OTHER	0/5 (17)	2/7 (8)	0/0 (3)	2/12 (28)
Total	6/16 (29)	2/12 (14)	5/6 (11)	13/34 (54)

The findings therefore do not imply that organisations without a dedicated TTO engage less in KT. Rather, they indicate different forms of KT and approaches to institutionalisation. A dedicated TTO may be highly relevant for organisations managing patents, licensing and frequent industry interactions, whereas organisations transferring knowledge primarily through policy outputs, publications, cultural works and other copyright-protected outputs may require different forms of support.

An additional issue is the sustainability of specialised support. The broader assessment indicates that financing of knowledge-transfer functions is often fragmented and dependent on project funding, which can constrain long-term development of professional support capacities. For smaller organisations, this raises the question of whether shared or interinstitutional services may represent a more sustainable solution than maintaining a complete internal TTO.

The largest institutionalisation gap becomes apparent when KT is considered in relation to organisational routines, incentives and monitoring. Although organisations generally report a supportive culture for applied research and recognise the societal and economic relevance of their work, KT is only moderately integrated into staff promotion and evaluation systems. Researchers' familiarity with institutional IP policies and procedures is also limited.

Formal IP management varies considerably. Among organisations providing an answer, 13 reported requiring systematic recording of intellectual property, while 16 did not. Similarly, 16 organisations reported an established process for taking over employee inventions, compared with 14 without such a process. These differences appear related to disciplinary profile: formal invention-management mechanisms are more

common in STEM organisations, while SSH organisations rely more strongly on copyright and other non-patent forms of knowledge protection.

Respondents' self-assessment of organisational culture and institutionalisation practices shows that the highest overall scores relate to the societal or economic contribution of research (4.5), encouragement of researchers to engage in innovation and KT (4.0), and a culture supporting applied research (3.9). Lower scores are reported for familiarity with IP procedures (3.3), patenting and IP protection (3.0), revenue-sharing and IP ownership protocols (2.7), spin-off support (2.5) and monitoring of licensing agreements and income (2.2). The composite indicators presented in Table 4 further illustrate the contrast between supportive KT culture and weaker formal embedding. The commercialisation indicator reflects patent-, licensing- and spin-off-oriented mechanisms and should not be interpreted as an overall measure of KT effectiveness.

Table 4. Organisational culture and institutionalisation of knowledge transfer by research orientation. Values represent unweighted composite mean scores on a five-point scale.

Research orientation	n	Supportive KT culture ¹	Formal embedding ²	Commercialisation mechanisms ³
ALL	6	4.3	3.7	3.3
SSH	12	4.1	2.8	1.5
STEM	16	4.1	3.2	3.2
Total	34	4.1	3.2	2.6

¹ *Supportive KT culture*: culture supporting applied research, encouragement to innovate and transfer knowledge, societal/economic contribution, and communication of KT success stories.

² *Formal embedding*: KT in staff evaluation and promotion, familiarity with IP procedures, and protocols for revenue sharing and IP ownership.

³ *Commercialisation mechanisms*: patenting/IP protection, monitoring of licensing agreements and revenues, and spin-off support.

Monitoring also remains uneven: STEM organisations more frequently use indicators such as patents, industry projects and spin-offs, whereas SSH organisations rely more on policy influence, dissemination and external engagement. Limited staff capacity, administrative burden and funding constrain systematic monitoring. Overall, the challenge is to translate strategic recognition into stable support, clear procedures, appropriate incentives and monitoring [9,10].

4 Conclusions

The findings show that strategic recognition of KT in Slovenian ROs is only partly accompanied by the structures, procedures and incentives needed for systematic implementation. Formalisation remains uneven across institutional and research profiles. STEM-oriented PROs tend to have more formalised structures, responding higher-education organisations more diversified support, and many SSH-oriented organisations more decentralised KT. Strengthening KT therefore requires differentiated institutional models reflecting dominant transfer

pathways, from IP management and commercialisation to policy engagement and other forms of knowledge valorisation.

The results also suggest that strengthening KT is not only a question of establishing dedicated support structures, but of aligning strategic objectives with internal procedures, incentives, professional support and monitoring. Institutional arrangements should recognise both commercial and non-commercial pathways of knowledge transfer and provide support appropriate to the research profile and organisational context.

Future research should combine the survey with qualitative interviews and case studies to examine how different institutional arrangements emerge and are experienced by researchers and KT professionals. This would help identify which organisational mechanisms are most effective under different institutional and disciplinary conditions and support the development of more context-sensitive KT models for Slovenian ROs.

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The Recognition and Operationalisation of Indirect Intellectual Property Benefits in Slovenian Innovation and Knowledge-Transfer Calls between 2009 and 2023

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Abstract

The paper examines how six Slovenian public calls issued between 2009 and 2023 recognised and measured the indirect benefits of intellectual property (IP). It distinguishes the legal effects of IP rights, direct commercialisation results and indirect strategic, relational, reputational, organisational, financial, ecosystem, educational and social benefits. The calls were analysed at five levels: whether a benefit was mentioned, financed as an activity, required as an output, used in selection, or measured as a formal result or impact. The development was non-linear. The 2009 and 2010 call supported broad innovation activities, the 2011 and 2013 call placed greater weight on market results and specialised commercialisation, and the 2017 and 2023 call broadened the role of transfer offices through professionalisation, training, networking, common infrastructure and knowledge valorisation. Organisational and ecosystem benefits received the strongest recognition, while strategic, reputational, investment-related, educational and ethical benefits remained less visible. Across all six calls, patents, research contracts, firms and commercial values remained the main performance indicators. At that time, the Ministry of Higher Education, Science and Innovation therefore broadened what transfer organisations were expected to do more quickly than what the Slovenian innovation system formally recognised as value.

Keywords

intellectual property; indirect benefits; knowledge transfer; technology transfer offices; knowledge valorisation; public calls

1 Introduction

Knowledge-transfer programmes (in Slovenia) often measure success through visible outputs such as patents, licences, research contracts, spin-offs and commercial income. These

measures are useful, but they capture only part of the value created by intellectual property (IP). IP can also clarify ownership, strengthen a negotiating position, support investment, signal technical competence, improve institutional visibility and make cooperation between research organisations and firms. [2–7]

A call may describe knowledge and technology transfer broadly, including training, networking, awareness, and institutional capacity, while judging success mainly by patents and research contracts. Indirect benefits may thus be important in the programme's logic but absent from its final indicators. The research question is therefore *'How did six Slovenian calls recognise indirect IP benefits, and which benefits remained weakly recognised or unmeasured?'*

2 Conceptual framework

The conceptual framework examines how IP creates value and how this value is reflected in funding programmes. It clearly distinguishes between immediate legal effects, direct measurable transactions, and the broader indirect benefits that drive long-term strategic growth.

2.1 Legal effects, direct results and indirect benefits

IP rights create legal effects, and depending on the right, the holder may be able to prevent certain uses, license or transfer the right, enforce it, and regulate relations with other parties. A patent is mainly an exclusionary right; it does not automatically give the owner an unconditional right to use the invention. Legal effects can support value creation, but they are not the same as commercial or organisational value. [1]

Direct results are linked to observable transactions or market outcomes: patents and other rights, licences, assignments, research contracts, new products, spin-offs and income. These results are easy to document and therefore attractive as programme indicators. However, they do not show whether IP improved a negotiation, attracted an investor, prevented a dispute or supported long-term cooperation. [3–7]

The seven categories used in this study are an analytical synthesis informed by issues previously identified in Slovenian practice [8], the European knowledge-valorisation and intellectual-asset-management frameworks [9–10], and published research on IP management in technology transfer offices [11]. These sources

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support a broader understanding of IP value beyond direct protection and commercialisation, including strategic use, collaboration, organisational capabilities, ecosystem development and broader economic and societal value. The categories used for the analysis are: (1) strategic benefits, such as stronger bargaining power, (2) relational benefits, such as clearer ownership and repeated cooperation, (3) reputational benefits, such as visibility and technical signalling, (4) organisational benefits, such as skills, rules and better decisions, (5) financial and investment benefits, (6) ecosystem benefits, such as shared tools and stronger links between research and industry, and (7) educational, ethical and social benefits, including responsible use of knowledge. [8]

A benefit can appear in a call at five levels. Discursive recognition means that it is mentioned in the purpose or justification. Operational recognition means that an activity intended to create the benefit can be financed. Output recognition requires a concrete activity or product. Selection recognition affects the assessment of applications. Performance recognition refers to a formal result or impact indicator. The distinction separates the programme's theory of action – what it funds and expects organisations to do – from its theory of value – what finally counts as success.

3 Data and method

The study uses a longitudinal qualitative comparison of the published texts of six calls. These six calls constitute the full set of major national public calls in Slovenia in this field between 2009 and 2023 and therefore provide a complete longitudinal sequence of the national funding instruments through which this policy area developed. The calls show what the state defined as a legitimate objective, an eligible activity, a required output, a selection criterion, and a measurable result. They do not show whether the programmes were implemented effectively or how aware all Slovenian researchers and firms were of indirect IP benefits. [2–7] (Table 1)

The first three calls supported a broad innovation environment. The 2011 call excluded public research and higher education institutions because their transfer offices were funded elsewhere. The 2013, 2017 and 2023 calls focused directly on technology or knowledge transfer at public research organisations. This change in institutional focus reflects the actual development of the national support system rather than a sampling choice, although it limits direct comparison between the earlier and later instruments. [2–7]

Each call was coded for the seven indirect benefit categories and the five recognition levels. The seven benefit categories were defined in advance through the literature-informed framework

described above [8–11] and were applied deductively to the six call texts. The five recognition levels were used as an analytical device to determine whether each benefit was mentioned, financed, required as an output, used in selection, or measured as a formal result or impact. The qualitative interpretation identifies where benefits appeared in the intervention logic – the analysis does not assign numerical effectiveness scores.

Although the six calls constitute the complete sequence of the major national instruments in this field, they differ in their target groups and institutional roles. The qualitative analysis compares policy design rather than programme effectiveness. A funded activity does not prove that the expected benefit occurred, and the published calls do not provide comparable implementation data across periods. The qualitative analysis therefore identifies formal recognition in the documents, not the economic or social benefits.

4 Results

An examination of calls from 2009 to 2023 demonstrates a non-linear evolution of the innovation support ecosystem, with an initial emphasis on market commercialisation followed by a shift toward the professionalisation of knowledge transfer. Over this period, indirect benefits such as institutional capacity building, staff training, and ecosystem cooperation evolved from general eligible activities to mandatory project outputs.

4.1 A non-linear policy development

The 2009 and 2010 calls used a broad innovation-support model. They financed education, networking, support for inventors and young people, regional activities and non-technological innovation. IP protection was only one service, and its financing was tied to an expected financial return. Indirect benefits were therefore present mainly as eligible activities rather than as separate outcomes. [2–3]

The 2011 call moved towards “innovation for the market”. Patents, firms, products, services and events became more explicit and attributable results. The 2013 call created a specialised public-research commercialisation model based on technology transfer offices, dedicated staff, internal rules, invention-disclosure procedures and measurable results such as patents, licences, research contracts and spin-offs. [4–5]

The 2017 and 2023 calls broadened the mission again. They financed professional staff, training, awareness, common platforms, networking, mentoring, strategic integration and cooperation across the innovation ecosystem. The 2023 call also recognised different missions of universities and research institutes and called for broader knowledge-valorisation metrics. Yet the principal indicators still focused on patent applications, contract values and new contracts with firms. [6–7]

Table 1: Documentary corpus

Call	Official publication	Institutional focus	Dominant policy orientation
INO 2009	Official Gazette RS, No. 36/2009, 15 May 2009	Approximately fifteen technology and innovation hubs serving a wide population	Broad support for technological development and innovation
INO 2010	Official Gazette RS, No. 22/2010, 19 March 2010	Technology and innovation hubs acting outside the consortium	Economically successful private-sector innovation and system improvement
INO 2011	Official Gazette RS, No. 28/2011, 15 April 2011	Innovation-support organisations focused on firms and the market	Innovation for the market and attributable results
KT 2013–2014	Official Gazette RS, No. 10/2013, 1 February 2013	One consortium of public research organizations and their transfer units	Specialised transfer into economic use
KT 2017–2022	Official Gazette RS, No. 30/2017, 16 June 2017	A national consortium of technology transfer offices	Professionalisation, strategic patenting and commercialisation
JR KTO 2023	Official Gazette RS, No. 131/2023, 22 December 2023	Two differentiated but cooperating knowledge-transfer consortia	Knowledge valorisation, competence development and ecosystem cooperation

4.2 Call-level evidence

INO 2009. The call had the broadest target group, such as firms, research organisations, associations, inventors, entrepreneurs, students and pupils. It financed education, networking, databases, competitions, regional support, research–industry cooperation and non-technological innovation. These activities could produce organisational, relational, reputational and ecosystem benefits. However, the call did not identify them as indirect IP benefits, and IP protection was deemed eligible only when the expected financial effect was several times the protection cost. Recognition was therefore mainly operational, while the underlying value logic remained financial. [2]

INO 2010. The 2010 call retained most of this broad set of activities but gave greater weight to economically successful private-sector innovation and higher-value products. It also financed proposals for improving the Slovenian innovation system. This was an early form of policy-learning and ecosystem recognition, but it remained an eligible activity rather than a formal impact. The same expected-return test for IP protection was retained. The call therefore combined broad operational support with a narrower commercial definition of value. [3]

INO 2011. The 2011 call shifted towards “innovation for the market”. Patent and design applications, new firms, products, services, training, and promotional events were more clearly defined and had to be linked to the support organisation’s work. Past results also affected the assessment of applicants. Indirect benefits, such as learning and visibility, shifted from general activities to required outputs, but they were closely tied to market introduction. The exclusion of public research organisations also marked a clearer division between the general innovation-support system and specialised public-research transfer offices. [4]

KT 2013–2014. The 2013 call created a specialised commercialisation model for public research organisations. It required organised transfer units, dedicated staff, internal rules for employee inventions, a formal disclosure point and a committee for protection decisions. These requirements gave strong recognition to organisational capacity in output and selection. Nevertheless, the programme’s final value was still expressed mainly through patents, licences, research contracts and spin-offs. The scoring model (60 % for past results and 40 %

for planned results) reinforced this focus on documented commercialisation performance. [5]

KT 2017–2022. The 2017 call was the clearest move towards professionalisation. It presented knowledge transfer as the third mission of public research organisations and financed new staff, training, awareness, a shared platform, a guide, promotion, company visits, partner search and links with technology parks and incubators. Several indirect benefits met the required output levels and selection criteria: (1) institutional capacity, (2) competence, (3) stakeholder interaction, (4) sustainability, (5) strategic integration, and (6) socio-economic impact. Even so, the central quantitative targets were 40 foreign patent applications, at least EUR 300,000 in licensing and knowledge-sale agreements, and EUR 8 million in research contracts. Indirect benefits were therefore strongly operationalized, primarily as routes to commercial results. [6]

JR KTO 2023. The 2023 call used the broader language of knowledge valorisation and recognised different missions of universities and public research institutes. It covered promotion, networking, common tools, mentoring, international learning, staff skills, monitoring and several forms of IP, including software, know-how and non-technological solutions. It also required work on common definitions and indicators for different valorisation channels. This was the broadest theory of action in the corpus. However, the two principal indicators remained 46 patent applications with substantive examination and 50 companies entering new contractual cooperation. The call thus recognised the need for broader metrics without yet using them as its main performance measures. [7]

4.3 Main cross-call findings

Table 2 shows three main results. Firstly, the development was non-linear: broad innovation support was followed by stronger market orientation and specialisation, and later by a broader but more professional model of knowledge valorisation. Secondly, indirect benefits moved from general language and eligible activities towards required outputs and selection criteria. This shift was clearest in 2017 and 2023. Thirdly, the shift rarely reached the level of performance indicators. Patents, research contracts, firms and commercial values remained the most authoritative evidence of success. [2–7]

Table 2: Recognition of indirect benefits across the six calls

Call	Discursive	Operational	Required outputs	Selection	Performance
INO 2009	Broad innovation, inclusion and transfer	Training, networking, IP support and non-technological innovation	Mainly reported support activities	No clear separate indirect-benefit criterion	Innovation activities; IP support tied to expected return
INO 2010	Private-sector innovation and system improvement	Training, networking, policy proposals and IP support	Service delivery and system proposals	Limited evidence of separate indirect-benefit criteria	Economically successful innovation
INO 2011	Innovation for the market	Training, promotion and market support	Patents, firms, products, services and events	Past results and attributable involvement	Patents, firms, market results and events
KT 2013–2014	Transfer of public research into economic use	Organised transfer units and IP management	Staff, rules, disclosure point and planned results	60% past and 40% planned results	Patents, licences, research contracts and spin-offs
KT 2017–2022	Third mission, public benefit and system links	Training, staffing, awareness, platforms and networking	30 FTE, guide, platform, events and strategic embedding	Culture, stakeholder links, sustainability and impact	Patent applications, licensing value and research contract value
JR KTO 2023	Knowledge valorisation and differentiated missions	Training, mentoring, common tools, networking and new metrics	Shared website, tools, training and monitoring activities	Capacity, cooperation and planned implementation	Patent applications and new contractual firm cooperation

The strongest recognition concerned organisational and ecosystem benefits: (1) staff, (2) training, (3) internal rules, (4) web platform, (5) networking and (6) cooperation. Strategic and reputational benefits were less explicit. Stronger bargaining power, better partnerships, reduced uncertainty, institutional reputation and technical signalling were rarely treated as outcomes. Investment readiness, IP valuation, private finance, IP literacy, responsible attribution, and wider ethical or social benefits were the least-developed categories. [2–7]

4.4 Results by benefit category

The category analysis confirms that the calls did not treat all indirect benefits equally (Table 3). Organisational and ecosystem benefits were the most visible. From 2013 onwards, the calls increasingly required dedicated units, staff, internal rules,

training, shared platforms and links with other stakeholders. Relational benefits were supported by networking, partner search, joint ownership arrangements, and cooperation, but the quality or durability of relationships was rarely measured. Strategic and reputational benefits were usually implicit. The calls supported activities that could improve bargaining power, visibility and credibility, but did not define these effects as formal outcomes. [2–7]

The early calls linked IP support to expected financial returns, while the later calls measured licensing and research contract values. They did not systematically measure investment readiness, private finance enabled by IP, or the use of intangible asset valuation. Educational elements were evident in training, researchers and students, and awareness. Responsible attribution, ethical use of knowledge, and public sector uptake were not treated as final indicators. [2–3, 6–7]

Table 3: Recognition of indirect-benefit categories

Benefit category	2009–2011 calls	2013–2023 calls	Overall result
Strategic	Market access and protection choices were mostly implicit.	Strategic patenting, partner search and joint ownership were supported.	Supported through activities, rarely measured as an outcome.
Relational	Networking and research–industry links were eligible activities.	Cooperation, partner search and common platforms became more formal.	Operational and output recognition, but little measurement of relationship quality.
Reputational	Promotion, events and awards could increase visibility.	Websites, databases and promotion made competences more visible.	Visibility was funded; reputation and credibility were not formal indicators.
Organisational	Training and support services were present but weakly differentiated.	Dedicated units, staff, rules, training, mentoring and strategic embedding were required.	Strongest indirect-benefit category; often reached output and selection levels.
Financial/Investment	IP support was linked to expected financial return.	Licence and research contract values were measured.	Commercial value was visible; investment readiness and valuation were weak.
Ecosystem	Broad target groups, regional support and international links.	Shared tools, consortia and links with innovation intermediaries expanded.	Strong operational recognition, limited direct performance measurement.
Educational / Social	Students, young people, training and non-technological innovation were included.	Training, students and public-benefit language continued.	IP literacy, ethics and social uptake remained weakly operationalised.

Table 2 and 3 led to the same conclusion. The calls became better at recognising the capacities and activities needed for knowledge transfer, especially those related to professional staff, cooperation, and shared infrastructure. They remained much less developed in measuring the strategic, reputational, relational and social value created by those activities. The gap is therefore not mainly between direct and indirect benefits, but between indirect

benefits as supported work and indirect benefits as formally recognised results.

5 Discussion and implications

The findings do not show that Slovenian calls ignored indirect benefits. The later instruments recognised many of them and made training, awareness, and cooperation central to the technology transfer process. The problem is their position in the

intervention logic. They were usually inputs, activities or required outputs expected to improve commercialisation, not final outcomes valued independently. [6–7]

A technology transfer office may improve the quality of an IP decision, strengthen a negotiation, build trust or create a useful partnership without this appearing in the main indicators. At the same time, a patent application may satisfy an indicator even when its strategic or economic value is uncertain. Indicators therefore shape priorities as well as record performance.

Future calls should retain patent and research contract indicators but add a small set of measures that align with the broader mission. Organisational indicators could include staff competence, assessment quality, and the adoption of IP strategies. Relational indicators could cover repeated cooperation, partner satisfaction and the quality of joint-ownership arrangements. Strategic indicators could record cases in which IP supported a negotiation, partnership, investment or a deliberate decision not to patent. Ecosystem indicators could cover referrals, shared tools and cooperation with investors and intermediaries. Educational and social indicators could cover researcher and student IP literacy, responsible attribution and public-sector use of knowledge.

Not every programme needs all these measures. The key requirement is consistency. When a call finances competence, trust, shared infrastructure or valorisation, at least some of these effects should also be visible in the formal definition of success.

6 Conclusion

Across the six Slovenian calls, the recognition of indirect IP benefits increased, but not in a straight line. Early calls supported broad innovation activities; the 2011 and 2013 instruments emphasised market results and commercialisation; and the 2017 and 2023 calls expanded the role of technology transfer offices through professionalisation, competence development, networking and knowledge valorisation. [1–6]

The main result is that the goal broadened faster than the performance system. Organisational and ecosystem benefits became visible in activities, outputs, and selection criteria, whereas patents, research contracts, and firms remained the main formal results. A more updated framework should therefore distinguish legal effects, direct commercialisation results and indirect benefits, and should measure at least some of the wider value that public calls already expect technology transfer organisations to create.

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Centralised Implementation, Fragmented Pathways? Innovation Support and Research–Industry Knowledge Transfer in Slovenia

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Abstract

Slovenia has centralised the implementation of research and innovation support within the Slovenian Research and Innovation Agency (ARIS). This paper examines whether this centralisation has created a functionally integrated pathway from research to industrial innovation. We analyse 16 innovation instruments included in the ARIS Programme of Work and Financial Plan for 2026, focusing on funding sources, industrial research (IR) and experimental development (ED), legal bases and conditions for participation of research and knowledge-dissemination organisations (RKDOs). The portfolio is strongly dependent on European Cohesion Policy funding and predominantly oriented towards ED. Only three of the 14 instruments directly supporting IR and/or ED, representing 21% of the analysed funding, enable RKDOs to participate as fully funded collaborative project partners. The study identifies RKDO funding conditions as a potential policy-design barrier to research–industry collaboration and highlights the need for further evaluation of portfolio coherence and its implications for Slovenia’s innovation performance.

Keywords

innovation policy, knowledge transfer, RKDO, industrial research, experimental development, ARIS, State aid, Slovenia

1 Introduction

Slovenia substantially centralised the implementation of research and innovation support following the adoption of the Scientific Research and Innovation Activities Act (ZZRID) in 2022 and the transformation of the Slovenian Research Agency (ARRS) into the Slovenian Research and Innovation Agency (ARIS) in 2023. However, as shown in our preceding analysis [1], centralisation of implementation has not necessarily resulted in consolidation of the policy portfolio, which remains distributed across ministries, policy areas and funding sources.

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The first innovation calls implemented by ARIS were launched in 2025, but many corresponding types of support existed previously under the SPIRIT Slovenia Business Development Agency (SPIRIT), the Ministry responsible for economy (MRE) and the Ministry responsible for science and innovation (MRSI). The transfer of innovation measures to ARIS is therefore important because the same implementing agency can now support both research organisations and companies.

This creates an opportunity for a more integrated research-to-innovation continuum. In knowledge-based economies, competitiveness depends not only on generating new knowledge but also on transferring, co-developing and valorising it. OECD assessments have identified persistent weaknesses in research–industry knowledge transfer in Slovenia and have emphasised the need for a balanced policy mix and effective institutional coordination [2, 3].

A functioning policy mix should avoid systemic gaps between research and industrial development. Industrial research (IR) should bridge the gap to experimental development (ED), while funding conditions should enable meaningful research–industry collaboration. State-aid rules permit higher aid intensities for IR than for ED because of its greater technological uncertainty [4].

The position of research and knowledge-dissemination organisations (RKDOs) is especially important. CRP V7-2145 developed proposals for a sustainable national State-aid model supporting research–industry collaboration [5], while MRSI subsequently established a State-aid framework under ZZRID that enables full funding of eligible RKDO activities under appropriate conditions [6].

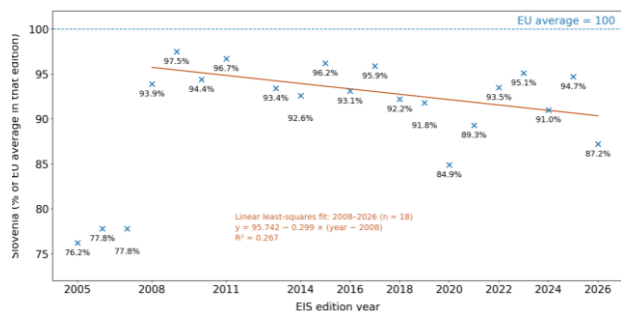


Figure 1: Slovenia relative to the EU average in annual EIS editions, 2005–2026. Linear fit is descriptive only and uses 2008–2026; 2005–2007 are excluded due to a significant revision of the measurement framework in the 2008 edition [7, 8].

The European Innovation Scoreboard (EIS) is used only as contextual evidence. Across the more methodologically comparable EIS editions since 2008, Slovenia's relative position has not shown sustained improvement (Figure 1) [7, 8].

The study examines 16 innovation instruments included in the ARIS Programme of Work and Financial Plan for 2026 [9] and asks: (1) whether innovation funding is expected to increase; (2) how strongly the portfolio relies on integral versus ECP funding; (3) how support is distributed between IR and ED; (4) to what extent instruments support research–industry knowledge transfer; and (5) whether their funding conditions enable effective RKDO participation.

2 Methodology

The analysis covers 16 innovation instruments. Fourteen directly support IR, ED, or both, while two — Strategic Research and Innovation Partnerships and the Competence Centre for AI — provide broader support functions and are classified as not relevant (nr) for the IR/ED comparison. Recurring calls belonging to the same substantive instrument were aggregated and their planned values summed.

Data on planned instrument values, annual funding, funding source and originating ministry were taken from the ARIS Programme of Work and Financial Plan for 2026 [9]. Legal basis, funding category and RKDO participation were derived from the financial plan and publicly available ARIS call documentation. Unpublished instruments are marked with an asterisk.

The RDI TRL 3–6 instrument was counted fully as IR for the aggregate comparison although it also permits ED; the calculated IR share is therefore an upper estimate. STEP was classified under ED for the funding comparison even though part of the instrument supports testing infrastructure and production-related activities. As a robustness check, STEP was excluded entirely; the qualitative result remained unchanged, with IR still representing only about one quarter of the IR/ED funding considered.

The European Innovation Scoreboard (EIS) is used only to provide context by showing Slovenia's result as a percentage of the EU average in each published annual edition. The values for 2005–2026 were compiled from consecutive EIS/IUS editions in an author-prepared source review [8], with the 2026 value additionally verified against the official EIS 2026 Slovenia country profile [7]. The figures do not form a harmonised time series because the indicators, normalisation, composition of the EU and reference years changed between editions. The comparison between funding developments and the EIS is therefore illustrative and cannot establish causality.

3 Results

3.1 Structure and legal basis

Table 1 summarises the 16 instruments. Four use ZZRID as the primary legal basis for beneficiary funding, while 12 use ZPOP. Among the 14 instruments directly supporting IR and/or ED, ZZRID-based instruments provide the clearest mechanisms for RKDOs to participate as fully funded collaborative project partners, whereas ZPOP-based instruments do not provide equivalent conditions.

3.2 Growth and funding structure

Planned innovation funding increases from EUR 59.18 million in 2026 to EUR 90.24 million in 2027 and EUR 116.69 million in 2028, nearly doubling over the period. Integral funding accounts for only approximately 4% in 2026 and 7% in 2027 and 2028, indicating strong dependence on ECP resources (Figure 2a).

Table 1a: Innovation instruments, planned values and funding sources

Instrument	€000	Source
MRSI: RDI TRL 3–6	58.753	ECP
MRSI: Eureka	21.450	ECP+I
MRSI: Eurostars 3	13.500	ECP+I
MRSI: Researchers in Economy	13.020	ECP
MRSI: EIC Accelerator	11.400	ECP
MRSI: TRL 5–8	10.000	I
MRSI: SRIP	7.889	ECP
MRSI: Researchers at Beginning of Careers	3.886	ECP
MRSI: Upgrades of Applicative Projects	2.804	ECP
MRSI: Innovation Voucher	1.000	I
MRE: STEP – East and West	90.000	ECP
MRE: RDI TRL 6–9	55.000	ECP
MRE: RDI DEMO PILOTS	14.420	ECP
MRDT: Innovation AI Projects	16.256	ECP
MRDT: Small-scale Applied AI Projects	6.400	I
MRDT: Competence Centre for AI	3.600	I

Table 1b: Funding category, legal basis and RKDO participation

Instrument	Funding	Legal	RKDO
MRSI: RDI TRL 3–6	IR+ED	ZZRID	YES
MRSI: Eureka	ED	ZPOP	NO
MRSI: Eurostars 3	ED	ZPOP	NO
MRSI: Researchers in Economy	ED	ZPOP*	NO*
MRSI: EIC Accelerator	ED	ZPOP*	NO*
MRSI: TRL 5–8	ED	ZPOP	NO
MRSI: SRIP	nr	ZPOP*	nr
MRSI: Researchers at Beginning of Careers	IR+ED	ZZRID	YES
MRSI: Upgrades of Applicative Projects	IR	ZZRID	YES
MRSI: Innovation Voucher	ED	ZPOP	NO
MRE: STEP – East and West	ED	ZPOP	NO
MRE: RDI TRL 6–9	ED	ZPOP	NO
MRE: RDI DEMO PILOTS	ED	ZPOP	NO
MRDT: Innovation AI Projects	ED	ZPOP*	NO*
MRDT: Small-scale Applied AI Projects	ED	ZPOP*	NO*
MRDT: Competence Centre for AI	nr	ZZRID	nr

Notes: I – integral state-budget funding; ECP – European Cohesion Policy 2021–2027; IR – industrial research; ED – experimental development; nr – not relevant for direct IR/ED funding. Legal – the primary legal basis for beneficiary funding. RKDO – research and knowledge-dissemination organisation; YES – fully funded collaborative participation possible under applicable conditions; NO – equivalent conditions not provided. * instrument not yet published by ARIS at the time of analysis.

3.3 IR versus ED

The funding structure is strongly weighted towards ED. Only three instruments provide differentiated higher funding treatment for IR, all originating from MRSI. Under the upper-bound methodology, IR represents up to 18% of innovation funding in 2026, 24% in 2027 and 19% in 2028; actual shares are lower because RDI TRL 3–6 also supports ED. The robustness check excluding STEP confirms that the predominance of ED is not driven solely by STEP's size.

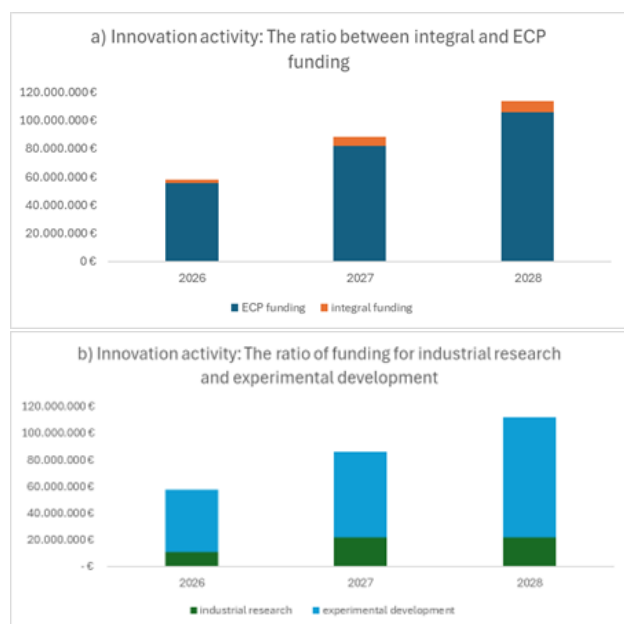


Figure 2: Projected innovation funding 2026–2028 a) by ECP and integral funding and b) for industrial research and experimental development.

3.4 Financial core and tail

Three instruments form the financial core: STEP (EUR 90.0 million), RDI TRL 3–6 (EUR 58.75 million) and RDI TRL 6–9 (EUR 55.0 million). The remaining instruments form a smaller tail (Figure 3). This extends the core-and-tail finding of the preceding portfolio analysis [1] by showing that the instruments also differ in TRL orientation, funding source and legal basis.

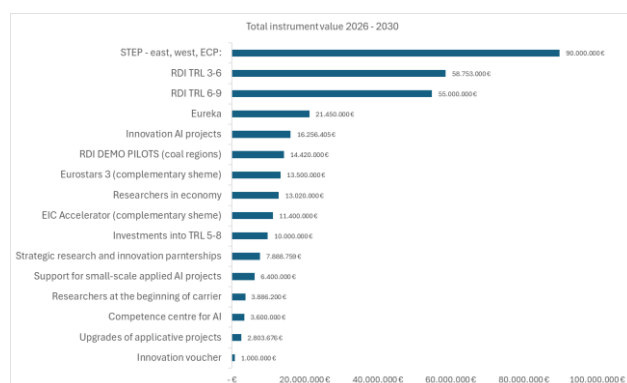


Figure 3: Innovation instruments by total planned value for 2026–2030.

3.5 RKDO participation and knowledge transfer

The legal basis is closely associated with the position of RKDOs. Of the four ZZRID-based instruments, three directly support IR and/or ED and enable RKDOs to participate as fully funded collaborative project partners; the fourth is a supporting instrument for which this classification is not relevant. The 12 ZPOP-based instruments do not provide equivalent conditions. This does not mean that they cannot facilitate knowledge transfer: the Innovation Voucher, for example, supports innovation services for SMEs delivered by research organisations. The distinction concerns the role of the RKDO within the funded

project: service provider or subcontractor versus fully funded collaborative partner.

4 Discussion

The results indicate that centralisation within ARIS has expanded innovation funding but has not yet produced equivalent functional integration of the research-to-innovation pathway.

First, the strong reliance on ECP resources raises questions about portfolio adaptability and long-term sustainability. ECP funding enables substantial additional investment, but it also ties instruments to programming cycles and broader coordination requirements. This is consistent with OECD recommendations on strengthening the coherence and sustainability of Slovenia's policy mix [3].

Second, funding is predominantly oriented towards ED. A single ED-level funding intensity can simplify implementation and reporting, but it removes the higher aid intensity available for IR, which is intended to compensate for greater technological uncertainty. The RDI TRL 3–6 instrument shows that IR and ED can be distinguished and funded accordingly.

Third, centralisation has not harmonised the legal bases of the instruments. ZZRID explicitly accommodates RKDOs and, through a valid State-aid scheme [6], enables their full funding under appropriate conditions, whereas ZPOP-based instruments do not provide equivalent conditions for RKDOs as fully funded collaborative project partners. The distinction is therefore not simply whether research organisations are involved, but how they are involved.

Subcontracting, contract research and innovation services differ from collaborative R&D in which RKDOs and companies contribute complementary knowledge, share development risks and address intellectual-property exploitation jointly. Effective research–industry knowledge transfer through collaborative R&D should therefore be based on partnerships in which research organisations and companies participate on an equal footing.

Figure 3 also suggests that several smaller instruments could potentially be treated as thematic or target-group modules within broader RDI funding families. This does not imply automatic merger: instruments originate from different ministries, funding sources and legal frameworks. It does, however, reinforce the portfolio-governance principle that new instruments should be assessed against existing funding families before separate architectures are created.

The present structure should also be understood as a transitional outcome. Many ECP instruments were designed within separate ministerial policy domains before ARIS's innovation function became fully operational. The resulting configuration may therefore reflect path dependence and programming constraints rather than an intentional design of fragmented research-to-innovation pathways.

Research–industry knowledge transfer is relevant to EIS performance, as the EIS framework includes indicators capturing linkages and collaboration within the innovation system [7]. Strengthening such linkages could therefore contribute positively to Slovenia's overall innovation performance. However, the relationship between individual innovation instruments and the aggregate EIS score is indirect, and the present analysis does not allow reliable predictions of future EIS performance.

The findings instead point to the need for further evaluation of the coherence of the innovation policy portfolio, particularly regarding the balance between IR and ED and the funding conditions that enable RKDOs to participate on an equal footing as fully funded partners in collaborative R&D projects.

4.1 Contribution of the study

A key contribution of this study is the identification of a specific policy-design barrier to research–industry collaboration that has received limited attention in previous assessments of Slovenia’s innovation system.

While previous studies have identified weaknesses in research–industry knowledge transfer, our instrument-level analysis shows that the funding architecture itself may constrain collaboration. Only three of the 14 instruments directly supporting IR and/or ED, representing EUR 65.44 million out of EUR 317.89 million (21%) of the funding analysed, enable RKDOs to participate as fully funded collaborative project partners. In the remaining 11 instruments, accounting for 79% of the analysed funding, RKDOs are either not eligible for funding as collaborative project partners or are subject to the same co-financing rates as enterprises.

Where RKDOs are funded under the same State-aid conditions as enterprises, their size typically places them in the large-enterprise category, resulting in a funding rate of 40% in most of the instruments analysed. This requires an RKDO to cover the remaining 60% of eligible project costs from other permissible sources, which, given the limited availability of own or market-based revenues to RKDOs, may substantially constrain their ability to participate in collaborative R&D projects.

Although RKDO activities may still be fully financed through subcontracting or the provision of research services, in such cases RKDOs do not participate as collaborative project partners and the treatment of their intellectual property therefore differs from that applicable to collaborative R&D projects under the State-aid framework [4].

This funding architecture may consequently limit opportunities for collaborative knowledge and IPR transfer between research organisations and industry, thereby providing a possible policy-design explanation for the low level of business use of IPR developed by public research organisations previously identified by the OECD [2].

5 Conclusion

The analysis shows a rapidly expanding innovation portfolio in which 14 of 16 instruments directly support IR and/or ED. Funding almost doubles between 2026 and 2028, but the portfolio depends heavily on ECP resources and is strongly oriented towards ED.

Four instruments use ZZRID as the primary legal basis for beneficiary funding, while 12 use ZPOP. Among direct IR/ED instruments, this distinction is associated with materially different conditions for RKDOs to participate as fully funded collaborative project partners.

The main challenge is therefore not simply the number or size of innovation instruments, but whether they collectively create a continuous research-to-innovation pathway. Future policy design should combine portfolio governance with a knowledge-transfer

perspective, paying particular attention to funding families, IR/ED balance, legal basis and the position of RKDOs within collaborative projects.

A key contribution of this study is the identification of funding conditions for RKDO participation as a potential policy-design barrier to research–industry collaboration. Only three of the 14 instruments directly supporting IR and/or ED, representing 21% of the analysed funding, enable RKDOs to participate as fully funded collaborative project partners. This instrument-level finding provides a possible explanation for previously identified weaknesses in research–industry knowledge and IPR transfer in Slovenia and warrants further evaluation of whether the innovation policy portfolio provides sufficiently coherent conditions for effective research–industry collaboration.

Research–industry knowledge transfer is relevant to EIS performance, but the relationship between individual innovation instruments and the aggregate EIS score is indirect. The present analysis therefore does not allow reliable predictions of future EIS performance. Further evaluation is needed to assess the coherence of the policy mix, particularly the balance between IR and ED and the conditions for RKDO participation on an equal footing as fully funded partners in collaborative R&D projects.

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