Towards the 4th generation university

The transformative role of TU/e in delivering innovation and impact in the Eindhoven region

ELSEVIER

SOURCE: BART VAN OVERBEEKE

Executive summary

Eindhoven University of Technology (TU/e) exemplifies the 4th generation university model, spurring innovation and societal development in the region. This report assesses the advancement of TU/e and its peers using quantitative metrics and serves as an invitation for further development of a holistic assessment framework.

Embracing the 4th Generation University Model
At a time when the role of academic institutions is rapidly evolving, Eindhoven University of Technology (TU/e) emerges as a trailblazer, transforming the landscape of higher education and research by embracing and exemplifying the 4th generation university model.

The 4th generation university model transcends conventional boundaries, championing an integrated approach to education, research, and innovation, with a strong focus on societal impact and regional development. A 4th generation university is actively engaged in co-creation processes with industry, governmental bodies, and civil society through trusted partnerships, fostering vibrant local innovation ecosystems. It's a global university, which embraces open innovation and is embedded in the local innovation ecosystem, aiming to tackle societal challenges and catalyze regional economic growth.

This report provides a comprehensive overview of TU/e as a 4th generation university during 2018–2022, using quantitative metrics to highlight the university's significant contributions to the Eindhoven area and beyond. The comparative analysis relies on a series of European benchmark universities with a similar profile and societal mission.

Gateway for Talent
The university acts as a critical gateway for talent. This report uses the indicator of alumni stay rates as a key to understanding TU/e's influence on regional innovation ecosystems and attractiveness. A pilot study based on a sample of TU/e alumni shows that 46.7% of alumni remain within 75 km of the university and 75.1% within the Netherlands. The report proposes a series of other indicators to measure the role of universities in attracting talent, which can be used in future assessments.

Joint Research with Industry
TU/e excels in joint research with local industry partners such as ASML, NXP Semiconductors, and Philips, proving a demonstrable ability to bridge academic knowledge with practical applications. With 14% of the university's total research output co-published with industry partners, TU/e emerges as an absolute leader in the comparator group. Nearly 46% of TU/e's publications with industry involved partners within 25 km from the university, demonstrating a balance between local and global knowledge exchange.

Dual University-Industry Appointments
TU/e boasts the second-highest share (4.6%) of researchers with dual university-industry affiliations among the benchmarks. Researchers

with dual affiliations to both universities and companies represent a vital bridge between the academic and commercial realms, facilitating a flow of advanced knowledge and skills. The instances of dual industry-university affiliations with co-publishing industry partners appear particularly prominent within 25 km from the university, with 75% of co-publishing industry partners hosting dual-affiliated researchers.

European Projects with Industry Partners
TU/e leads among the comparators in the share of European Commission-funded (EC) projects with private partners as well as the number of projects with private partners considering the size of the university. This achievement highlights a strategic industrial integration and commitment to driving innovation that enhances European competitiveness. Attracting European Commission research funding, particularly through programs like Horizon 2020 and Horizon Europe, is a critical indicator of a university's integration with the industrial ecosystem. TU/e's key EC project partners within 25 km from the university include NXP Semiconductors, Philips and SMART Photonics—a company that spun out of TU/e in 2012.

Alignment with Key Enabling Technologies
Alignment with the key enabling technologies (KETs) is crucial as part of the 4th generation university model, underpinning the university's ability to contribute effectively to societal and economic advancements. TU/e's research output is strongly aligned with Dutch KETs, with nearly 60% of TU/e's total output addressing KET areas, which is the highest share among the comparators. TU/e is most specialized in such KETs as Quantum Technologies and Photonics and Optical Technologies.

Patent Co-Ownership with Industry
Patent co-ownership analysis highlights TU/e's efforts to convert academic research into practical, market-oriented solutions. While these efforts show promise, there is room for improvement in terms of expanding the overall size, global technology relevance, and market coverage of its jointly-owned patent portfolio with corporate partners. TU/e's most prominent patent co-owner is Philips. It should be noted that while patent ownership is an important indicator of industry engagements, TU/e's commercialization strategy has been more focused on other areas, such as supporting spinouts. This nuance highlights the importance of accounting for different approaches that universities can adopt to leveraging industrial partnerships and commercialization.

Knowledge Utilization by Industry
Academic knowledge produced by TU/e contributes to the development of patented technology, hinting at a wider impact of academic research on practical applications. The share of TU/e's patent-cited publications output stands at 4.1%, putting it fourth among the comparators. The biggest industrial users of TU/e research are ASM International, Microsoft and Philips, all of which have cited TU/e's research in developing their patented technologies.

Spinouts and alumni-founded companies
TU/e has a sizeable portfolio of spinout companies launched in 2013–2022[1], of which 90% are situated within 75 km from the university, indicating a strong alignment of the spinouts' technological needs with the resources and market opportunities offered by local innovation ecosystems. Strong examples of such spinouts and start-ups include innovative renewable energy companies like RIFT, ELEO and Lightyear, high tech companies like SMART Photonics and advanced robotics companies Avular and Microsure.

Besides university spinouts, TU/e also exerts a strong influence on the regional start-up

1 This analysis used a longer timeframe to accommodate the extended period required for the development and maturation of spinouts and alumni-founded companies.

ecosystem through shaping entrepreneurial talent. Nearly 48% of start-ups founded by TU/e alumni between 2013 and 2022 are headquartered within 75 km of the university. Among these, companies such as MedApp, a smart online pharmacy, and Wefabricate, an innovative manufacturing platform, stand out as the most closely located to the university and largest in terms of employee numbers.

Joint Governance of Local Innovation Ecosystem
In addition to TU/e's performance in measurable quantitative outcomes of ecosystem engagement, the university plays a much broader role in the Brainport Eindhoven ecosystem through actively participating in ecosystem leadership, co-creation platforms, knowledge infrastructures, capital facilities, cultural embedding, and international networks. TU/e contributes to the thriving innovation hub in the region, driving advancements in fields like advanced manufacturing, robotics, and smart mobility while emphasizing sustainability and societal impact.

Further Development of 4th Generation University Indicators
This report serves as an invitation for further collaboration with technical universities, for which a core mission is nurturing local innovation and knowledge ecosystems.

The ultimate goal of this report is to jointly refine these quantitative indicators and measures of progress and set a collaborative framework for defining how universities can significantly contribute to innovation ecosystems.

Preface

The Eindhoven University of Technology has the privilege to educate talent and conduct academic research in the thriving high-tech ecosystem Brainport Eindhoven and in a time when technology development will make a huge impact in solving the big societal challenges of today. Through this ecosystem, our students, researchers and professionals can create global impact by collaborating with entrepreneurs and R&D-professionals only a bike ride away.

Like colleagues in other universities, we see that the emergence of innovation ecosystems is creating new demands for universities. Transdisciplinary and challenge-based education, mission-driven research and partnerships with industry are examples of these new demands. But foremost, our stakeholders look to the university to take the initiative for joint strategy development, to create joint research and education roadmaps and to be the gateway of new talent—students and research talent—for the ecosystem as a whole. As a result, knowledge creation and dissemination undergo a revolutionary transformation, redefining relationships across the academic, industrial, governmental, and societal landscape.

As already signalled by EUA and JRC, this development has required us to rethink our mission and strategy to fully enable the role of the university as driver of the innovation ecosystem. We identify the university that emerges from these trends as the 4th Generation University. Now, as the Brainport region will scale up further and our university aims to increase its impact on the growing innovation ecosystem, we actively use this concept to develop our strategy for the next 10 years.

This is why we are very excited to engage in this collaboration with Elsevier to present TU/e as an example of the 4th Generation University and learn from other universities as they advance in their regional innovation ecosystems. Based on Elsevier's world-leading experience in translating metrics into meaningful insights, a sound foundation is laid to explore the 4th generation university. With this report as a basis we hope to benchmark Eindhoven University of Technology with our partners in Europe, gain inspiration and work with them to enhance our role as driver of the innovation ecosystem.

Robert-Jan Smits
President, Eindhoven University of Technology

As we stand on the precipice of a new era defined by technological advancements, the role of universities has never been more crucial. The Eindhoven University of Technology (TU/e), nestled in the heart of innovation in the Netherlands, emerges as a beacon of transformative education, research, and knowledge transfer. This report examines the local impact of TU/e, an institution emblematic of the 4th generation university paradigm.

In the landscape of higher education, 4th generation universities like TU/e transcend traditional boundaries, bridging academia with industry, society, and government involving these stakeholders early on in their discoveries. They epitomize a dynamic ecosystem where innovation thrives, fostering interdisciplinary collaboration and driving tangible societal change.

Within these pages, we'll uncover some of the many ways in which TU/e leaves its mark on Eindhoven and its surroundings: the Brainport area. From groundbreaking collaborative research that fuels economic growth to initiatives that nurture entrepreneurship, TU/e is more than just a campus—it's a driving force behind the region's innovation engine.

The university's influence extends far beyond these metrics. It's about the people whose lives are touched by TU/e's educational programs and technological breakthroughs, outreach efforts, and commitment to social responsibility. Through a dedicated agenda focused on sustainability, diversity and the well-being of the Eindhoven community, TU/e is not just shaping minds, but also shaping a better world.

This report is an invitation to a partnership. We invite all like-minded universities to join a program where we will use and analyze data about the various functions of the 4th-generation university and allow them to compare their progress with peers and tell the story of how they use global knowledge to make a difference in their local communities.

Judy Verses
President, Academic and Government Markets, Elsevier

SOURCE: BART VAN OVERBEEKE

Contents

SOURCE: SICCO VAN GRIEKEN

The 4th generation university

The report aims to provide insights about the transition to the 4th generation university model, offering an initial framework for comparative analysis with peer institutions. To do so, it assesses the development of the Eindhoven University of Technology (TU/e) as a 4th generation university using quantitative measures, highlighting the transformative role of TU/e in fostering innovation ecosystems and societal development in the Eindhoven area.

Evolving role of universities in innovation ecosystems

The role of academic institutions in society is rapidly changing. All across the globe, the importance of talent and innovation as the major factors in economic competitiveness and societal welfare is acknowledged. Governments look to universities for contributions to societal transitions and economic prosperity. At the same time, economic competitiveness is driven by the expansion of regional innovation ecosystems in which companies, governments, knowledge institutions and societal partners stimulate knowledge transfer and entrepreneurship by engaging in multi-stakeholder partnerships. In this context, universities are emerging as key drivers of such innovation ecosystems.

What is an innovation ecosystem?

The European University Association (EUA) has pinpointed essential components that characterize innovation ecosystems, including organized leadership, joint strategy development, innovation brokers and facilitators, infrastructure development and a coordinated focus on external opportunities and societal challenges.[1] In addition, the Dutch government views innovation ecosystems as "a dynamic set of interrelated actors, activities, facilities and rules that are important for the research and innovation capability of individual actors and groups of actors and, through this, for the creation of value."[2]

Brainport Eindhoven stands out as an excellent example of such an innovation ecosystem. Several major companies, such as Philips, ASML, NXP Semiconductors and VDL Groep, and knowledge institutions such as TU/e have joined forces as part of the Brainport board and Brainport Development, implementing a joint strategy to address socio-economic development in the region.

1 European University Association (2019). The Role of Universities in Regional Innovation Ecosystems
2 Dialogic (2020). Onderzoeks- en innovatie-ecosystemen in Nederland

The 4th Generation University

In these organized innovation ecosystems, a transformation of the role of the university is taking place and the mission and organization of the university are profoundly changing. In 2009, the notion of a 3rd generation university was introduced[3] to describe a university that is becoming a more active participant in value creation and knowledge transfer processes. However, even in this short space of time, we are already noticing new developments in how the role of the universities is perceived. Key to this advancement is that a further conceptual step is taken: moving beyond knowledge transfer to enabling value creation in the innovation ecosystem more broadly. Where knowledge transfer implies that the university generates value and "transfers" it to the private or public sector, the role of creating value in an ecosystem is based on mission-driven collaborative knowledge creation, open innovation and multi-stakeholder partnerships in the setting of a regional innovation ecosystem. A university driven by these values can be referred to as a 4th generation university.[4]

Several trends originate from this transformation or reinforce it: the transition from education to challenge-based learning, from technology-driven innovation to mission-driven innovation, and from technology management in companies to value chain management. It gives rise to new units within universities, such as innovation spaces, and to new multi-stakeholder partnerships with a specific focus on challenges or technologies. It also raises discussions about the general governance of the university and how it should be adapting to enable these transformations.

	3rd Generation		4th Generation
Goal	Education, research and knowledge transfer	▶	Mission-driven (challenge-based) education, research and valorization
Role	Create value	▶	Enable societal value creation
Method	Interdisciplinary research	▶	Transdisciplinary research and multi-actor innovation
Human capital	Researchers, professionals and entrepreneurs	▶	Researchers, professionals, entrepreneurs, artists, customers, ecosystem participants
Orientation	Global orientation	▶	Ecosystem orientation
Organization	Institutes, centers	▶	Innovation spaces
Interaction	Industrial partnerships	▶	Integration in global and local ecosystems
Technology integration	Digital instruments	▶	Advanced technology and AI integration

Table 1

Key characteristics (selection) of the 4th Generation University as compared to the 3rd generation university model.

Source: (Marcel Bogers and Maarten Steinbuch[5])

3 Wissema, J.G. (2009). Towards the Third Generation University: Managing the University in Transition

4 Pawłowski, K. (2009). The 'Fourth Generation University' as a Creator of the Local and Regional Development

5 Bogers, M., & Steinbuch, M. (2023). De vierde generatie universiteit: Het nieuwe tijdperk van open innovatie en ecosysteemdenken. Holland Management Review, 208: 62-71

Fostering innovation ecosystems through diverse partnerships
The multi-stakeholder partnerships will continue to be of paramount importance for driving innovation ecosystems. They may range from formalized agreements, institutes and roadmaps on the highest level to joint positions of individuals in companies and knowledge institutions and student teams taking up challenges within a specific roadmap. Together they enable co-creation of knowledge and alignment goals within education, research and valorization[6] across the boundaries of organizations. Key to these partnerships is the proximity of the people involved: innovation takes place where people can easily meet.

Global university acting locally
Another hallmark of the 4th Generation University is that it combines a focus on the regional innovation ecosystem with a global outlook. The Brainport ecosystem exemplifies this approach, with the leading European companies in the semiconductor industry strongly connected to global players or targeting the global market, all while drawing from and enriching the local innovation pool. By taking the approach of co-creation of knowledge and joint strategy development in these tightly-knit and interconnected value chains, TU/e creates global impact by focusing on the value creation in the regional ecosystem.

Embracing the 4th Generation University model
From this transformation, the 4th Generation University emerges not as a mere participant in such an ecosystem, but as a key driver of the innovation ecosystem. Through its long-term commitment, its public and open character and its pivotal role as a gateway for worldwide talent and fundamental knowledge, it is able to take the initiative in joint strategy development and engage its students and researchers in value creation with partners in the ecosystem.

The Eindhoven University of Technology serves as an example of the transition towards the 4th Generation University but has a number of peers in other innovation ecosystems that share these characteristics. Together they can sharpen the concept of the 4th Generation University and share their experiences and best practices as drivers of the innovation ecosystem. This report takes a step in this direction by proposing a quantitative assessment framework to spark such a dialogue and exchange of ideas.

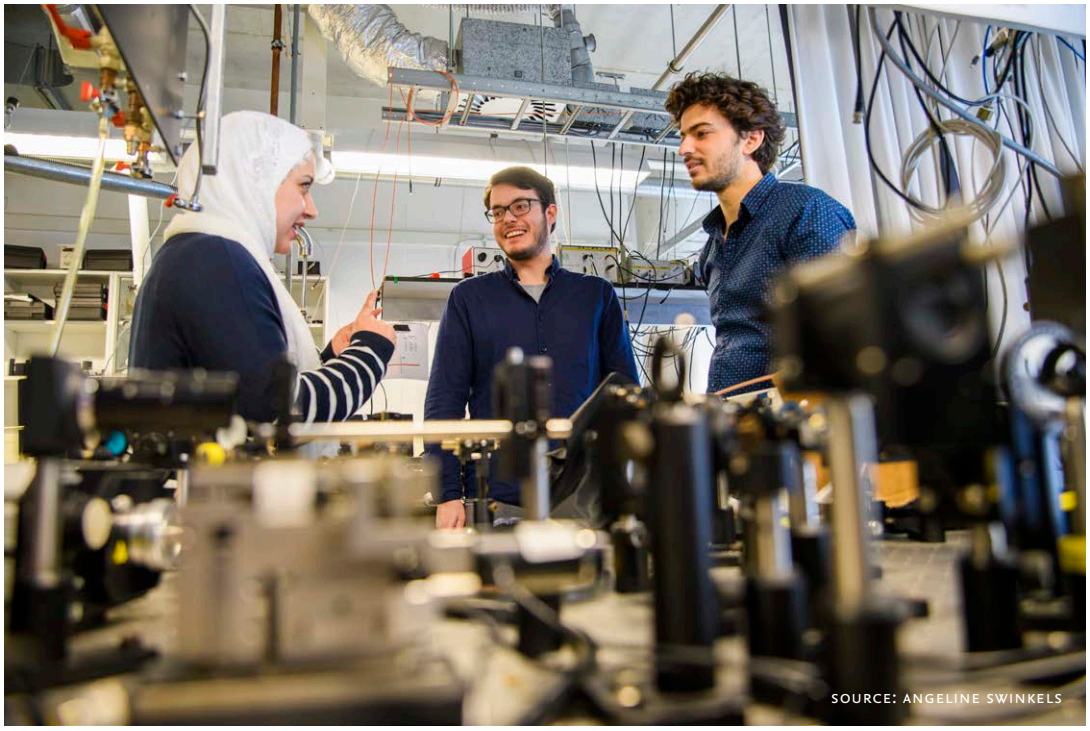
Structure of the assessment
This report aims to provide insights about the transition to the 4th generation university model, offering an initial framework for comparative analysis with peer institutions. While the report delineates various indicators for such a comparative assessment, not all elements of the framework could be used in a comparative manner. The entire methodological framework is introduced in a subsequent section, but one important distinction can be made between the types of analysis used in the report:

Benchmark analysis: The core of our analysis examines the fundamental functions of the 4th generation university, namely research (explored in sections 2–5) and the facilitation of knowledge transfer/valorization within the ecosystem (explored in sections 6–8). This

6 *"Knowledge valorization is the process of creating social and economic value from knowledge by linking different areas and sectors and transforming data, know-how and research results into sustainable products, services, solutions and knowledge-based policies that benefit society"* (EU Valorization Policy).

examination leverages data and indicators that allow for a comparative assessment of TU/e and its national and European counterparts (introduced in the next section).

Pilot analysis focusing on TU/e: Certain components, holding equivalent significance within our framework yet absent from the comparative part of the analysis, include talent creation and retention (discussed in section 1) and ecosystem governance (discussed in section 9). These elements are integral to the conceptualization of a 4th generation university and are earmarked for a detailed comparative exploration in a forthcoming assessment exercise following this report. The future analysis will enable participating universities to engage in benchmarking based on contributed data. For the current report, our presentation of data specific to TU/e employs pilot methodologies as a foundational step for broader comparative exploration.



SOURCE: ANGELINE SWINKELS

Setting the benchmarks: TU/e and its peers

The push towards the 4th generation university model is visible throughout Europe. To develop an assessment, this report benchmarks TU/e against several universities with a similar profile, mission and societal role in the Netherlands and other European countries.

This report benchmarks TU/e against several peer European universities selected for their pivotal role in leading vibrant knowledge and innovation ecosystems, thereby contextualizing TU/e's standing both within a European and a national framework. The complete list of comparator institutions comprises the following organizations:

- Delft University of Technology (NLD)
- Eindhoven University of Technology (NLD)
- Institut Polytechnique de Paris (FRA)
- Swiss Federal Institute of Technology Lausanne (CHE)
- Technical University of Denmark (DNK)
- Technical University of Munich (DEU)
- Technion-Israel Institute of Technology (ISR)
- University of Twente (NLD)

While this report initiates a foundational exploration into quantitative indicators for assessing the alignment with the 4th generation university model, we acknowledge the challenge in fully quantifying university contributions to innovation and societal development, proposing this document as an invitation for further collaboration with other engineering research universities with a similar mission. Our goal is to jointly refine these indicators and source reliable data, setting a collaborative path for defining how universities can significantly contribute to innovation ecosystems and socio-economic development in their regions.

Methodological framework

This report ventures into new methodologies to assess the dynamic role of universities in shaping local innovation ecosystems and their mission-driven alignment with key enabling technologies.

Designing a Framework to Assess the 4th Generation University
Transitioning towards the 4th generation university model involves a comprehensive transformation in how universities interact with their surrounding innovation ecosystems. This paradigm emphasizes not merely the academic and technological achievements or research outputs in isolation but evaluates the universities' roles as dynamic participants in regional development, innovation, and socio-economic growth.

Dimensions of analysis
The framework for assessing a university's development as a 4th generation university, therefore, is designed to capture the essence of these interactions, particularly focusing on the partnerships and engagement with local innovation ecosystems through the lens of four main dimensions: Talent, Research, Valorization and Governance.

The dimension of **Talent** focuses on the 'gateway for talent' role of the university, exploring alumni stay rates in the region. This analysis of this dimension is to be expanded in future assessments by incorporating other indicators, such as student population in key disciplines. The dimension of **Research** analyzes university engagements with co-publishing corporate entities, corporate partners as part of European Commission funded projects, and the alignment of university research with key enabling technologies[7]. The dimension of **Valorization** covers corporate patent co-owners, corporate organizations relying on university research for their patented technologies, university spinouts, and alumni-founded companies. Finally, **Governance** covers multiple aspects of organized participation of the university in the local innovation ecosystem development.

The specific indicators within each dimension of analysis are summarized in ***Table 2***.

Local innovation ecosystems and geospatial dynamics
This report explores new methodologies for analyzing the role of universities within local knowledge ecosystems, distinct from conventional approaches to university impact assessments. Central to our analysis is the exploration of new dimensions and indicators, particularly focusing on the geographical proximity between universities and their industrial ecosystem partners.

7 Elsevier (2024). Quantitative analysis of Dutch research and innovation on key technologies

Prior studies have emphasized the multiple benefits of university activities, particularly knowledge spillovers, for economic development near the universities.[8] Evidence suggests that these benefits decrease with increasing distance from the university, which is why this report adopts the framework of classifying university engagements with partners as within 25 km, 25–75 km, and >75 km from the university.

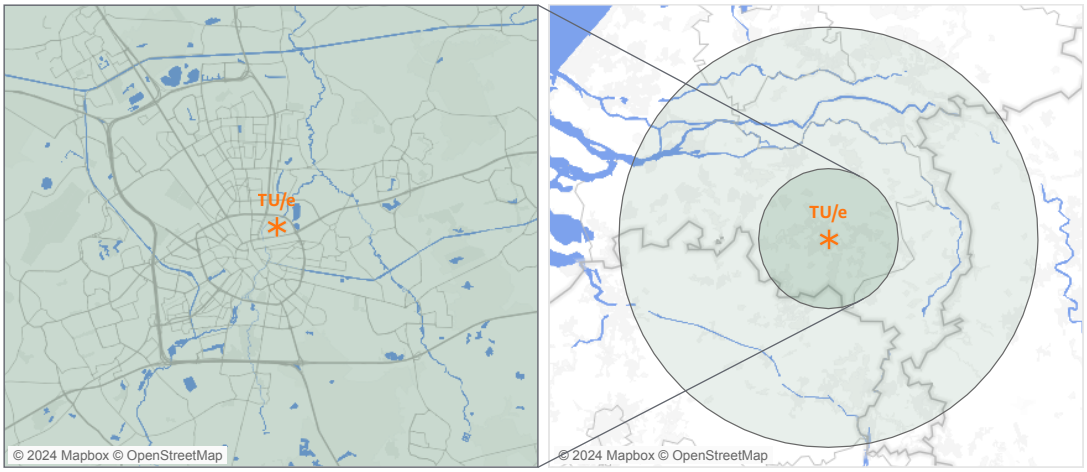


Figure 1
The geographical areas of 25 km and 25–75 km used to identify proximity of university partnerships and engagements.

Alignment with key enabling technologies
Additionally, we assess universities' alignment with key enabling technologies (KETs), guided by the Dutch KET framework. This critical analysis determines if universities' research priorities align with current technological and societal demands. In this report, we focus on eight key technology families, as outlined by the Dutch Ministry of Economic Affairs and Climate Policy, with contributions from TNO and NWO. A recent Elsevier report, commissioned by the Dutch Ministry of Economic Affairs and Climate Policy,[9] developed search queries to define these key enabling technologies, applied here at the technology family level. The technology families covered are:

- Advanced materials
- Photonics and optical technologies
- Quantum technologies
- Digital and information technologies
- Chemical technologies
- Nanotechnology
- Life sciences and biotechnologies
- Engineering and manufacturing technologies

8 Centraal Planbureau (2017). De Regionale Impact van Universiteiten: een Literatuuroverzicht
9 Elsevier (2024). Quantitative analysis of Dutch research and innovation on key technologies.

Scope of analysis
This report integrates multiple data sources, resulting in slight variations in the scope of analysis across different indicators. For the majority of the analysis, the period from 2018 to 2022 is considered. An exception is made for the analysis of spinout and alumni-founded companies, which extends from 2013 to 2022. This extended timeframe accommodates the longer periods required for the establishment and maturation of such companies.

In assessing the collaborative publication output with corporate partners, we include all publication types indexed in Scopus. This comprehensive approach is ideal to accurately identify instances of collaboration between universities and the corporate sector. Conversely, the analysis focusing on alignment with key enabling technologies (KETs) is limited to articles, reviews, and conference proceedings. This selection criteria prioritize the research excellence and novelty of university contributions to these pivotal technologies.

Co-designing the framework: an open invitation to refine and expand the assessment
Our methodology involves both established and experimental approaches, leveraging a variety of data sources to explore university engagements with their innovation ecosystems. This approach allows us to assess the intensity and nature of collaborations, the flow of knowledge and technology transfer, and the broader economic and societal impacts of these interactions. The geographical component of our analysis provides a unique perspective on the physical closeness of these collaborations, highlighting the importance of regional innovation ecosystems and the role of universities as central nodes within these networks.

Recognizing the challenges of developing new methodologies and the constraints of available data, we present this report as a preliminary foray and a call for further study and cooperation. Our objective is to spark dialogue and foster the creation of tools for evaluating universities' contributions to innovation ecosystems. This investigative work seeks to enrich the discourse on the 4th generation university model and its capacity to foster societal and economic advancement through deeper integration with both local and international innovation networks.

Dimension	Analysis	Indicator/Approach	Data source/s
Education	Alumni stay rates	• Share of university alumni remaining within 25 km, 25–75 km and more than 75 km from the university	LinkedIn
Research	Joint research with industry	• Share of academic–corporate publications	Scopus
		• Share of academic–corporate publications with corporate collaborators within 25 km, 25–75 km and more than 75 km from the university	
		• Share of corporate collaborators within 25 km, 25–75 km and more than 75 km from the university	
		• Geographical proximity distribution of corporate collaborators	
	Dual university–industry appointments	• Share of university researchers with dual academic–corporate affiliation	Scopus
		• Geographical proximity distribution of corporate organizations hosting university researchers with dual corporate affiliation	
	European projects with industry partners	• Share of EC projects (Horizon 2020 and Horizon Europe) with private partner participation	CORDIS Scopus
		• Number of EC projects with private partner participation per 100 publishing university researchers	
		• Share of EC funding value to university for projects with private partner participation	
		• EC funding value to university for projects with private partner participation per 100 publishing university researchers	
		• Share of EC projects with private partners within 25 km, 25–75 km and more than 75 km from the university	
		• Share of EC project private partners within 25 km, 25–75 km and more than 75 km from the university	
	Alignment with key enabling technologies (KETs)	• Share of KET publication output relative to total institutional output	Scopus
		• Citation impact of KET output	
		• Share of KET output in top 10% most cited publications	
		• Specialization vs citation impact per KET family	
		• Average year-on-year output and citation impact growth per KET family	

Valorization	Patent co-ownership with industry	• Size of patent portfolio co-owned with industry partners per 1,000 university publications	PatentSight Scopus
		• Market coverage of industry co-owned patent portfolio	
		• Technology relevance of industry co-owned patent portfolio	
		• Top industry co-owners of university patent portfolio	
	Knowledge utilization by industry	• Share of university's patent-cited publication output	PATSTAT PatentSight Scopus
		• Number of patent citations per 1,000 publications	
		• Top industry organizations citing university research in patents	
	Spinouts and alumni-founded companies	• Share of university spinout companies within 25 km, 25–75 km and more than 75 km from the university	Dealroom
		• Geographical proximity distribution of spinout companies	
		• Share of university alumni-founded companies within 25 km, 25–75 km and more than 75 km from the university	
		• Geographical proximity distribution of alumni-founded companies	
Governance	Ecosystem leadership	• The role of the university in the regional strategy-setting platforms and organizations	Contributory
	Co-creation platforms	• Participation or membership of university in co-creation programs	
		• Participation of university in joint regional knowledge and innovation platforms: campuses, open thematic networks.	

	Partnerships	• Strategic long-term and formalized collaborations with specific focus, in three categories:
		  • with companies on specific R&D/societal challenges
		  • with societal organizations on specific R&D/societal challenges
		  • sponsored professorships and cross-appointments	

	Knowledge infrastructures	• Joint or shared R&D and education facilities with industry, societal partners and/or regional educational partners, e.g. labs, pilot-plants, living labs.	
	Capital facilities	• Regional funding programs to stimulate value creation with knowledge partners and entrepreneurship based on research and education results, e.g. regional innovation funds, venture capital.	
	Cultural embedding	• Participation of the university in programs aimed at enhancing the social fabric of the ecosystem, e.g. spouse programs, international community, community service.	
	International network	• International networks of innovation ecosystems that the university and/or the ecosystem organization participate in.	

Table 2

Summary of dimensions, indicators and data sources used in analysis.

1. Gateway for talent

The university is a principal gateway for talent into the ecosystem. Fostering the development of talent therefore is a key function in the analysis of a 4th generation university. This section focuses on the stay rate of alumni as a crucial indicator of a university's educational relevance, as well as the region's attractiveness and opportunities for career growth. A pilot analysis for TU/e found that 46.7% of TU/e alumni remain within 75 km of the university, with 75.1% staying in the Netherlands.

Alumni stay rates are a vital metric for gauging a region's appeal in terms of employment opportunities, quality of life, and career advancement possibilities, all of which are essential for regional development and competitiveness. Thus, aiming to keep alumni within the region is paramount for any university looking to enhance local knowledge and innovation ecosystems.

Unlike other metrics, we have not compared the alumni stay rate with peer institutions. We invite like-minded universities to participate in an exercise that will encompass all metrics, including these, based on a joint collection of relevant data.

There are no flawless methodologies for assessing alumni stay rates. However, one methodology that was tested by Elsevier for TU/e involves data from social networking platforms, specifically LinkedIn, to track the educational and professional trajectories of alumni. This process encompasses the identification of individuals stating TU/e in their education history, followed by a detailed analysis of their geographic locations post-graduation.

In the case of TU/e, a sample of 2.1k profiles from a total of 69k was used to capture a representative subset of the alumni population, accounting for various degree types and graduation cohorts.

The analysis based on this sample shows that 30.4% of TU/e alumni remain within 25 km from the university with an additional 16.3% within 25–75 km from the university. Moreover, 75.1% of TU/e alumni remained in the Netherlands.

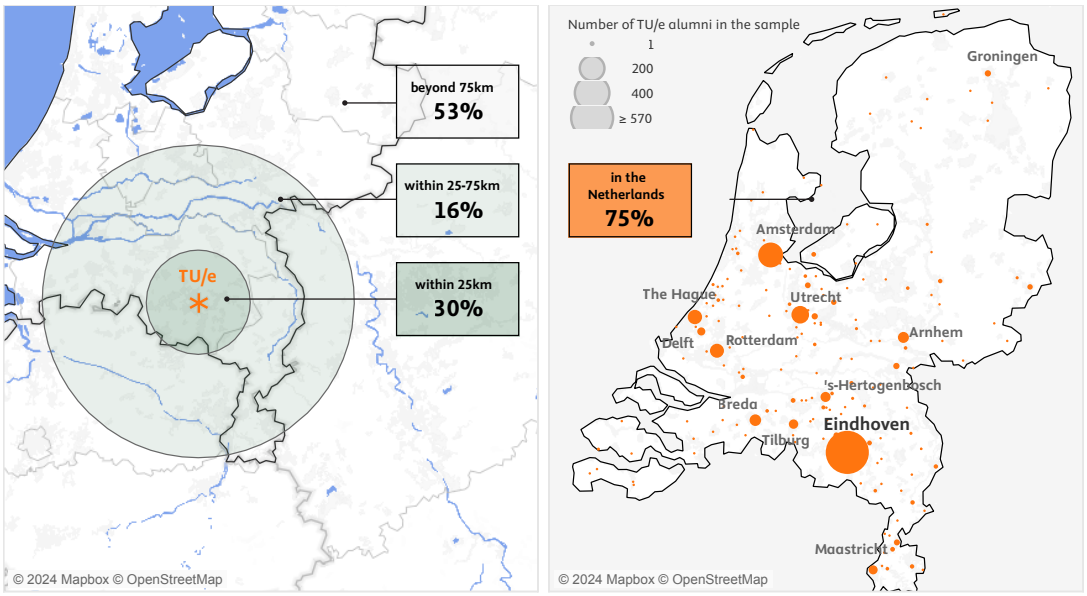


Figure 2

Alumni stay rates for TU/e based on pilot sample analysis.

Source: LinkedIn

Several caveats should be noted regarding the methodology. The reliance on LinkedIn data introduces a bias towards individuals who actively maintain their profiles and those more likely to use social media for professional networking. Additionally, the accuracy of location data and the distinction between the place of work and residence are potential sources of error. The dynamic nature of careers today, with frequent job changes and the rise of remote work, further complicates the precise measurement of stay rates.

Next to alumni stay rates, there are various other indicators that may generate additional insights into the talent attraction role of the university in the ecosystem. These indicators can be explored in future assessments:

- Number of graduates: the number of graduates indicates the impact the university may have for the region. Ideally, this would be measured against an indicator of the size of the region.

- Number of graduates in certain disciplines: similar to the key enabling technologies in research, educating talent in these key topics may indicate relevance for technological innovation.

- Number of international students: this number can generate insights into the appeal of the university on an international scale. However, it will be highly influenced by national policies and educational capacity restraints in popular fields of study.

2. Joint research with industry

Situated at the nexus of academic excellence and industrial innovation, TU/e shapes the future of innovation within the region through research collaborations with local industry leaders including ASML, NXP Semiconductors and Philips.

Why is this important?
Research with industrial partners allows university researchers to apply specialized academic knowledge to solve real-world problems.

How is it measured?
The engagement between benchmarks and industry partners is assessed by counting and geographically mapping collaborations resulting in publications.

Collaborative research output between academia and industrial partners stands as a key measure of a university's ability to bridge theoretical knowledge with practical applications, thereby fostering innovation and technological advancements. This synergy not only enhances the relevance and applicability of research findings but also plays a role in driving economic growth and addressing societal challenges.

By examining the overall share of this academic–corporate output for TU/e and the benchmarks, we can gain initial insights into the extent of universities' research engagement with industry. Among the comparators, TU/e stands out with the highest proportion of academic–corporate publications as a percentage of its total research output (***Figure 3***). Overall, the analysis places all the comparator institutions above the global average of 2.7% in terms of academic–corporate collaboration share, indicating their dedication to fostering partnerships with the industrial sector.

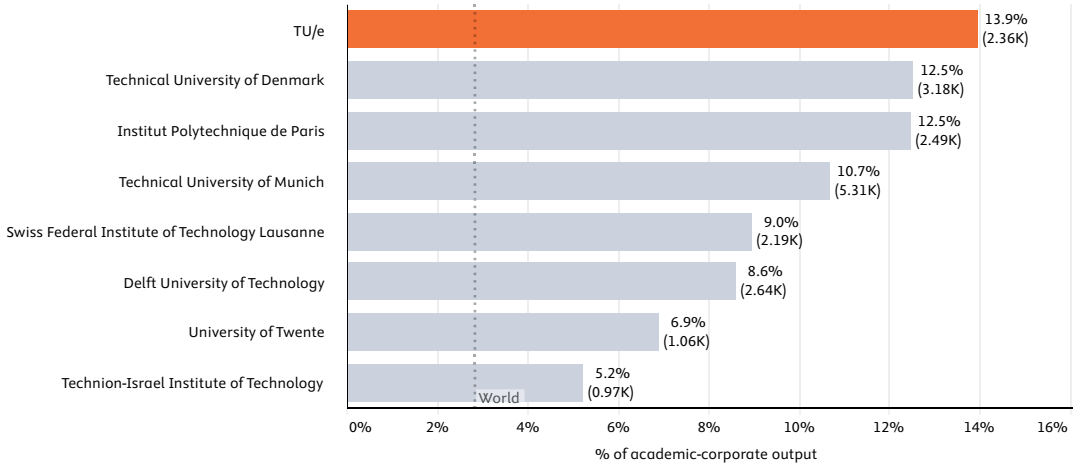


Figure 3
Share of academic–corporate output (2018–2022). The absolute number of publications with academic–corporate collaboration is shown in brackets.

Source: Scopus

Analyzing the geographical proximity of these collaborations—whether they occur within <25, 25–75, or more than 75 km from the university—sheds light on the local and regional impact of these partnerships. Close-proximity collaborations can indicate a strong regional innovation ecosystem, where the university acts as a critical node in a network of industry interactions, facilitating rapid knowledge transfer and fostering a culture of innovation. In contrast, wider geographical partnerships may reflect the university's broad reach and influence, attracting national and international industries to leverage its research capabilities, as well as increasing the potential for strong academic impact.

This distinction between local and global collaboration is crucial for understanding the spatial dynamics of innovation ecosystems and the role of universities in catalyzing economic development both locally and globally.

TU/e shows a balance between local collaborations, and those likely extending beyond the national borders. In the period from 2018 to 2022, academic–corporate publications with collaborators within 25 km of the university accounted for 46% of total academic–corporate publications (***Figure 4***). This joint research was conducted with 24 partners located within 25 km of the university, which constituted 5% of all TU/e's corporate collaborators.

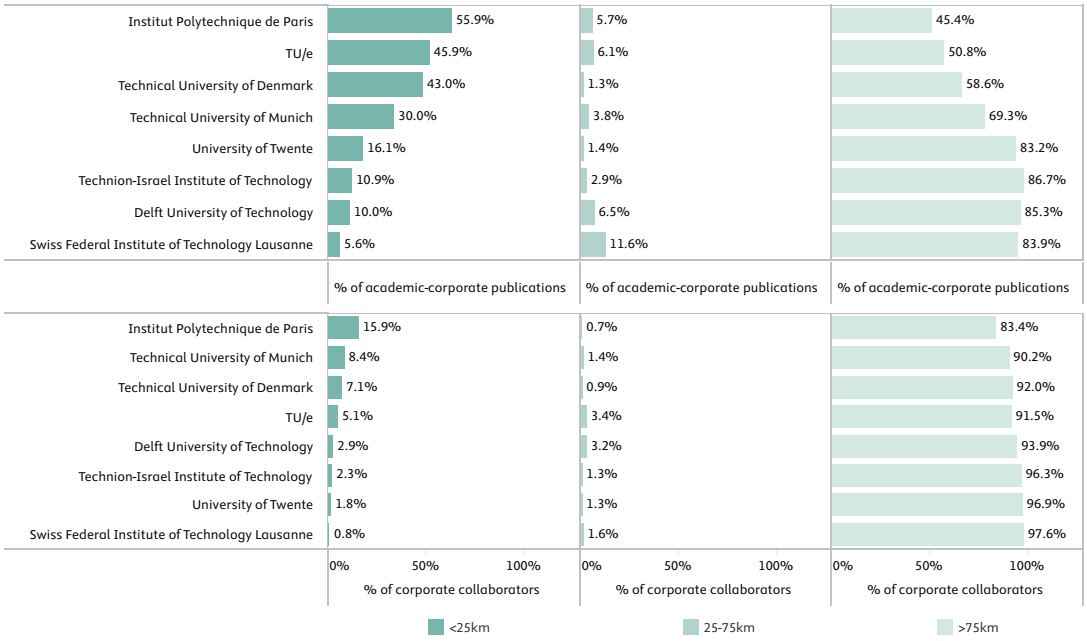


Figure 4

***Top**: Share of academic–corporate publications by distance between the university and corporate collaborators. Note that a single publication can be classified into multiple distance categories due to the involvement of collaborators at varying distances. Therefore, the bars may not add up to 100%. The universities are sorted based on the share of publications with collaborators within 25 km from the university. **Bottom**: Share of unique corporate collaborators by distance between the university and collaborators. As opposed to publications, each collaborator is assigned to only one distance category. The universities are sorted based on the share of collaborators within 25 km of the university.*

Source: Scopus

Among the comparators, Institut Polytechnique de Paris shows the highest share of publications with industrial partners located within the 25 km radius. In stark contrast, some benchmark universities appear to have most of their academic–corporate output co-published with partners beyond the 75 km radius. The most notable examples are Swiss Federal Institute of Technology Lausanne, Delft University of Technology and Technion-Israel Institute of Technology.

A more granular view of the distribution of industrial partners by distance from the benchmarks reveals unique variations in the proximity patterns (***Figure 5***). In most cases, however, there is a distinct concentration of industrial partners within specific, narrow distance ranges. These geographical clusters highlight the existence of preferred geographic locations for collaboration for each university.

The earlier mentioned Institut Polytechnique de Paris is a unique case with over 50 industrial partners in the range from 10 to 25 km from the university. In turn, the Eindhoven University of Technology has most of its local industrial partners within just 10 km from the university.

Figure 6 provides a focused view of TU/e's industrial collaborators, pinpointing their actual geographic locations and highlighting the key partners by volume of joint output: Philips, ASML, NXP Semiconductors, and Dutch Polymer Institute, among others. Within a 25 km radius, these strategic partnerships with TU/e are not just geographically convenient; they are also integral to the Brainport Eindhoven agenda, driving high-tech growth and innovation.

These relationships stand as exemplary models of university–industry synergy, advancing regional technological ambitions and knowledge exchange. ASML's leadership in semiconductor photolithography, NXP's innovations in automotive and connectivity, Philips' pioneering work in healthcare technology, and Dutch Polymer Institute's expertise in forging industry-led polymer research exemplify the unique contributions to this vibrant collaborative ecosystem. Together, they amplify TU/e's research capabilities and fuel the region's trajectory towards cutting-edge development and commercialization.

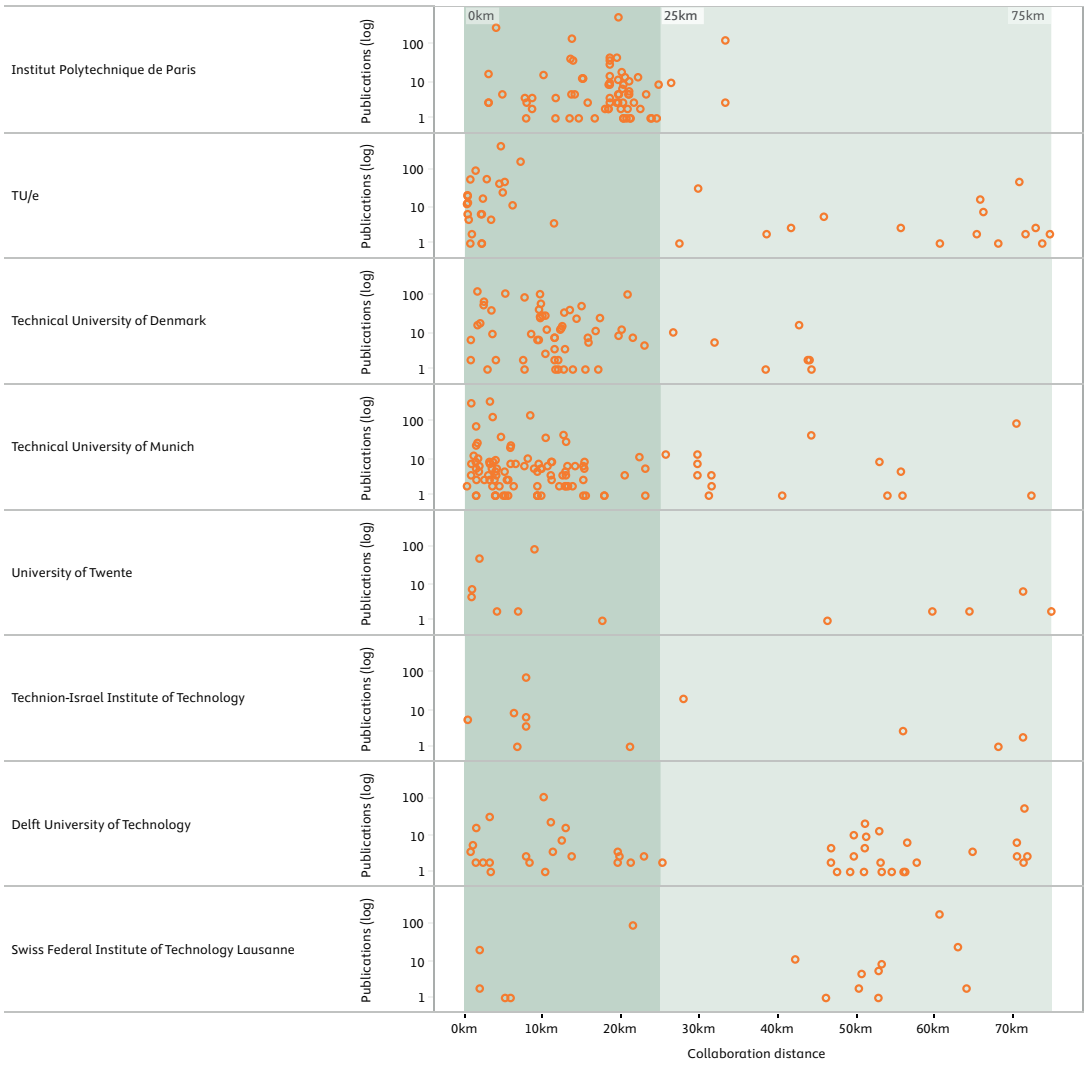


Figure 5

Distribution of industrial collaborators by distance from the university (horizontal axis) and number of joint publications (log vertical axis).

Source: Scopus

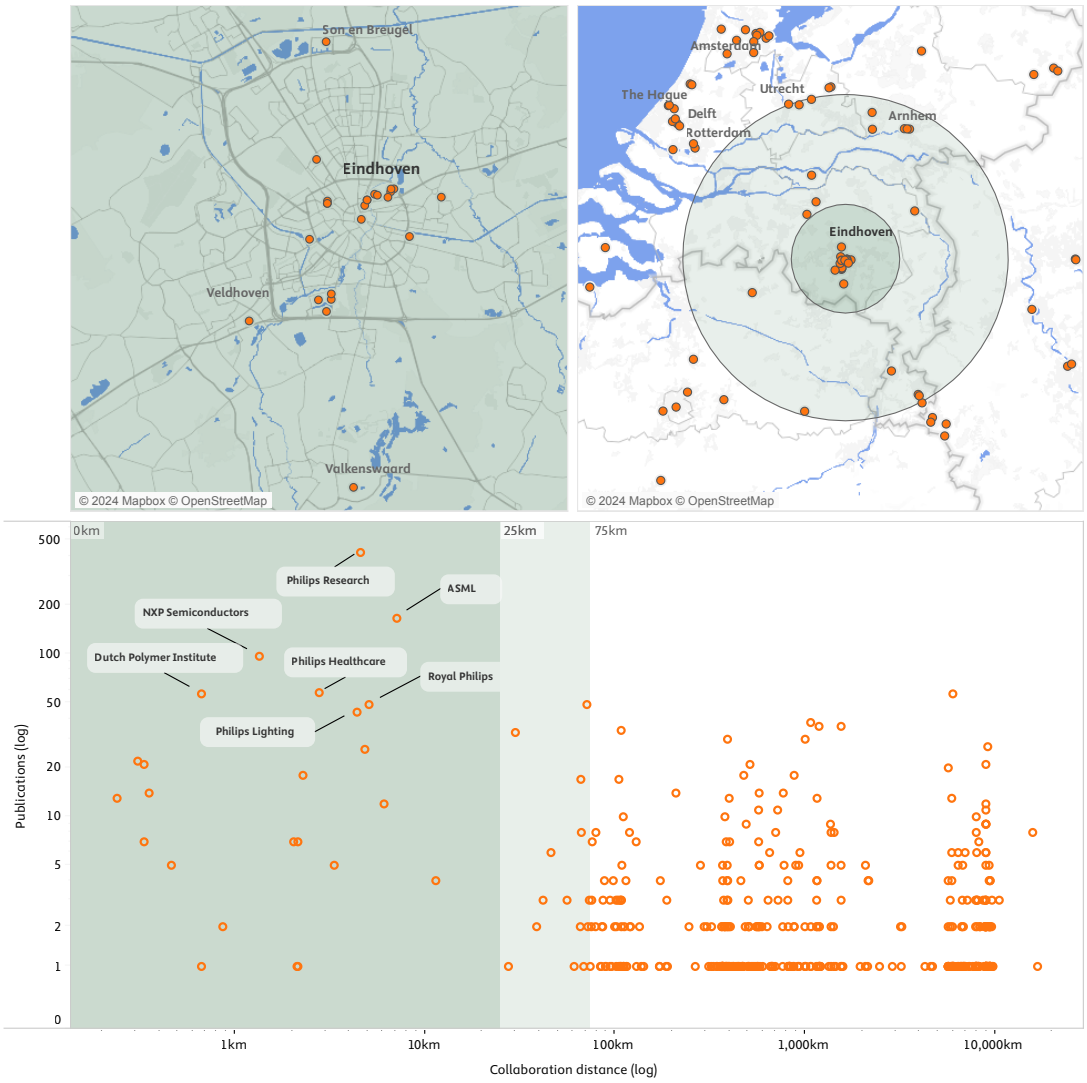


Figure 6

Bottom: *Distribution of industrial collaborators by distance from TU/e (log horizontal axis) and number of joint publications (log vertical axis).* ***Top right:*** *Geographical representation of industrial collaborators located within 25 km and 75 km of TU/e.* ***Top left:*** *Geographical representation of industrial collaborators in the immediate proximity of TU/e.*

Source: Scopus

3. Dual university–industry appointments

TU/e boasts a high share of researchers with dual university–industry affiliations. Local industry leaders, such as ASML and NXP Semiconductors, are among the biggest hosts for TU/e researchers with industrial affiliations.

Why is this important?
Dual appointments ensure a flow of advanced knowledge and skills between academia and industry, fostering a culture of applied research at the university.

How is it measured?
The share of publishing researchers who state a dual academic–industry affiliation in their papers is captured and serves as a strong signal of dual appointments.

Researchers with affiliations to both universities and companies represent a vital bridge between the academic, industrial and societal realms. While safeguarding academic standards and autonomy, these dual-affiliated researchers embed industry experience in the academy and enhance the relevance of research agendas, driving forward socially relevant innovations. Their presence within universities can also enrich the educational experience for students, who gain insights into the practical applications of their studies and the dynamics of industry challenges.

In the comparator group, the TU/e has the second highest share of such researchers bridging academia and industry (***Figure 7***). First among the comparators is the Institut Polytechnique de Paris whose share of dual-affiliated researchers is twice as high.

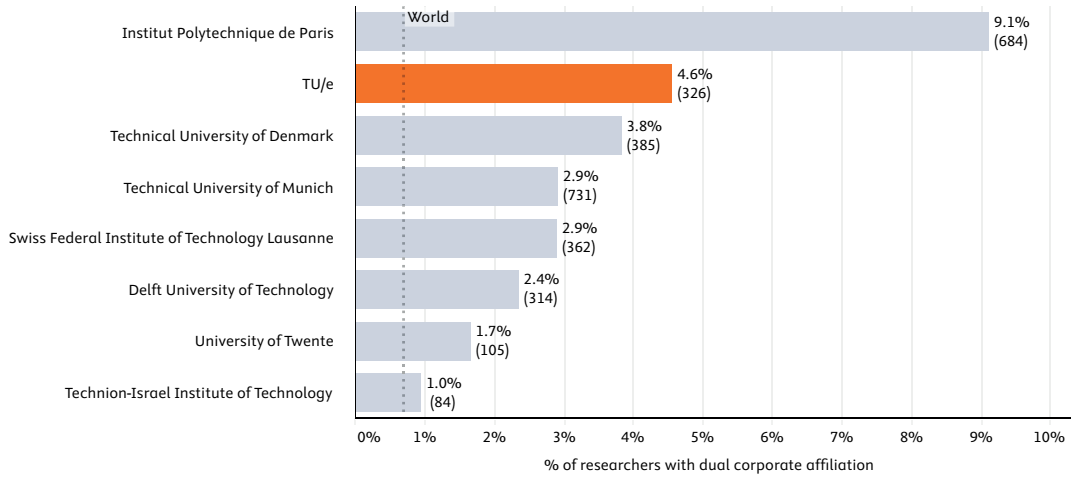


Figure 7
Share of university researchers with a dual corporate affiliation (2018–2022). The absolute count of researchers is shown in brackets.

Source: Scopus

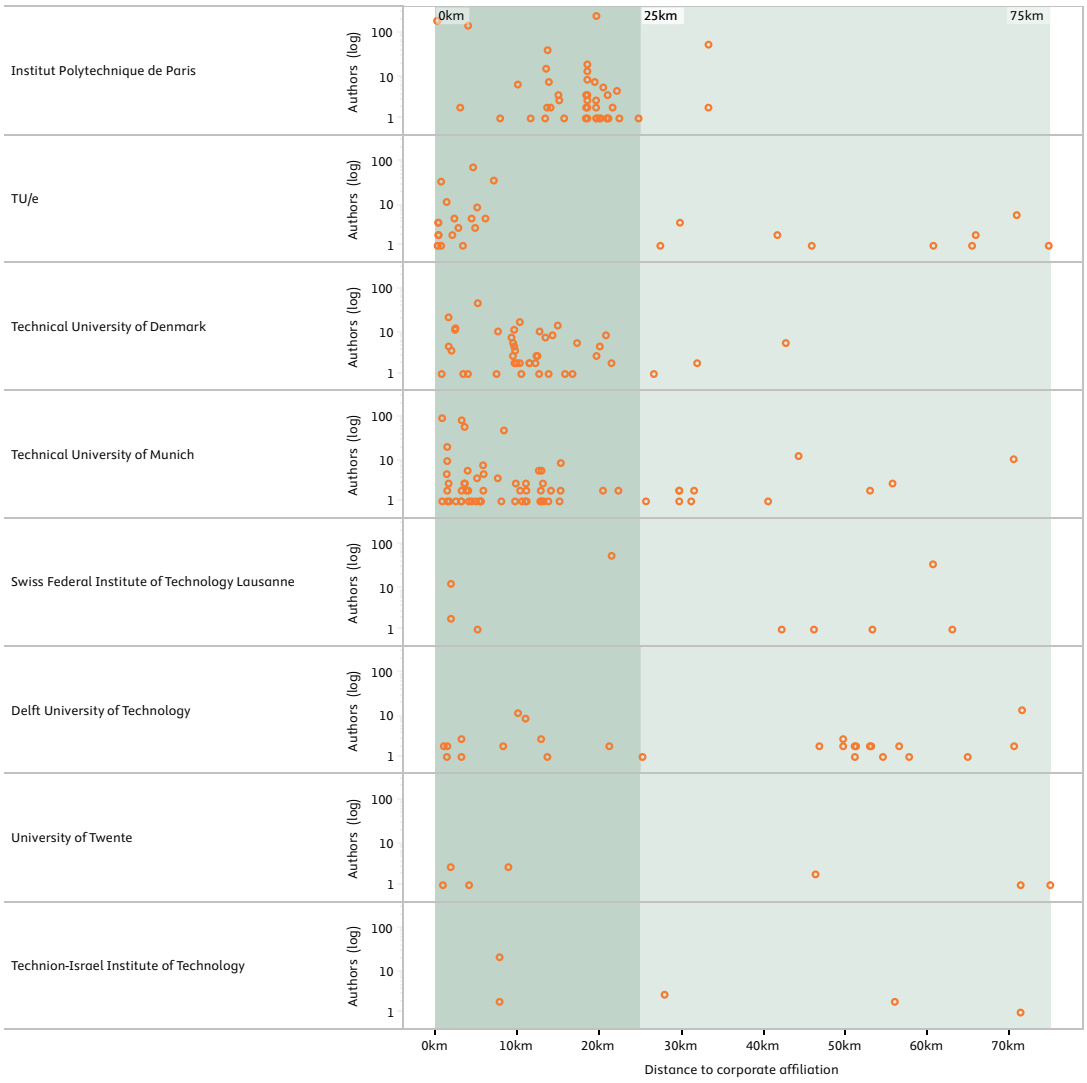


Figure 8

Distribution of TU/e's industrial collaborators with which university researchers have dual affiliations by distance from the university (horizontal axis) and number of joint publications (log vertical axis).

Source: Scopus

The focus on TU/e reveals that the most prolific industrial collaborators, in terms of joint research output, are those that accommodate the largest contingent of researchers with dual affiliations to both the university and the industry (***Figure 9***). Specifically, within a 25 km radius, TU/e boasts collaborative research publications with 24 industrial partners, 18 of which host researchers with the TU/e affiliation. However, while numerous corporate organizations engage in co-publishing with TU/e beyond the 75 km radius, the instances of co-publishing with dual-affiliated researchers are notably fewer. This distinction underscores the complex relationship between geographical proximity and the nature of academic–industrial collaboration. It also shows that dual affiliations are strongly supported by embedment in close proximity collaborations.

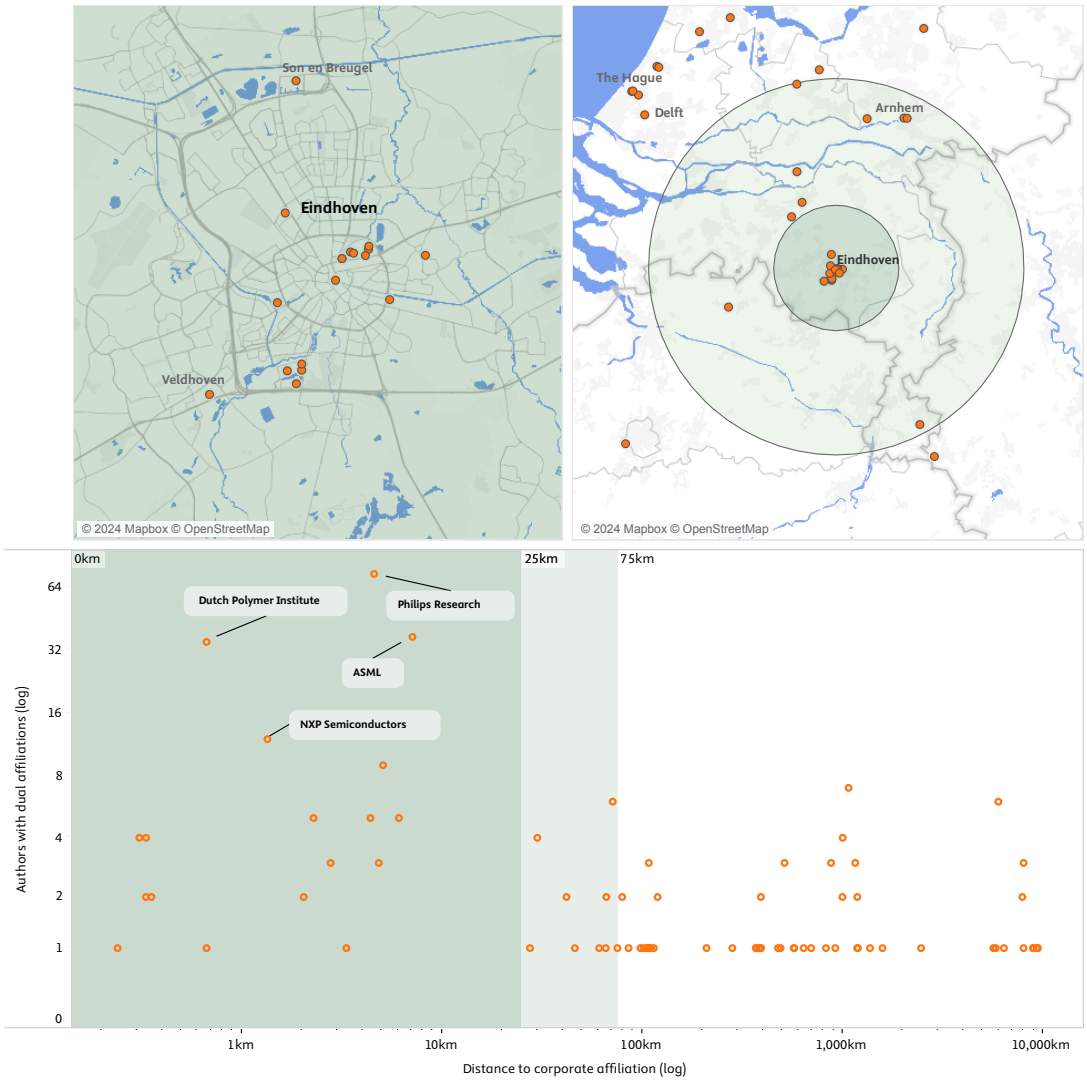


Figure 9

Bottom: *Distribution of TU/e's industrial partners with which university researchers have dual affiliations by distance from the university (log horizontal axis) and number of joint publications (log vertical axis).* ***Top right:*** *Geographical representation of industrial partners with which university researchers have dual affiliations located within 25 km and 75 km of TU/e.* ***Top left:*** *Geographical representation of industrial partners with which university researchers have dual affiliations in the immediate proximity of TU/e.*

Source: Scopus

4. European projects with industry partners

TU/e leads in the share of European Commission-funded collaborations with private partners, showcasing a strategic industrial integration and commitment to driving innovation that enhances European competitiveness.

Why is this important?
Industry collaborations funded by the EC demonstrate a strong alignment between government, industry and academia fostering the advancement of Europe's strategic priorities.

How is it measured?
Capturing and geographically locating Horizon 2020 and Horizon Europe partnerships between the universities and private entities.

Attracting European Commission (EC) research funding, particularly through programs like Horizon 2020 and Horizon Europe, in projects that include industrial partners, serves as a critical indicator of a university's integration with the industrial ecosystem. This engagement not only demonstrates the university's capacity to align with Europe's strategic research and innovation priorities but also underscores its ability to foster long-term strategic partnerships focused on innovation rooted in academic research.

Among the comparators, TU/e has the highest share of EC-funded projects with private partners and second highest number of projects with private partners per 100 active researchers (***Figure 10***). Despite the overall number of EC-funded projects with private partners being lower than for some comparators, TU/e's focus on engaging in projects with industry involvement is notable. This rate of participation in projects with the private sector highlights TU/e's alignment with the EC innovation agenda.

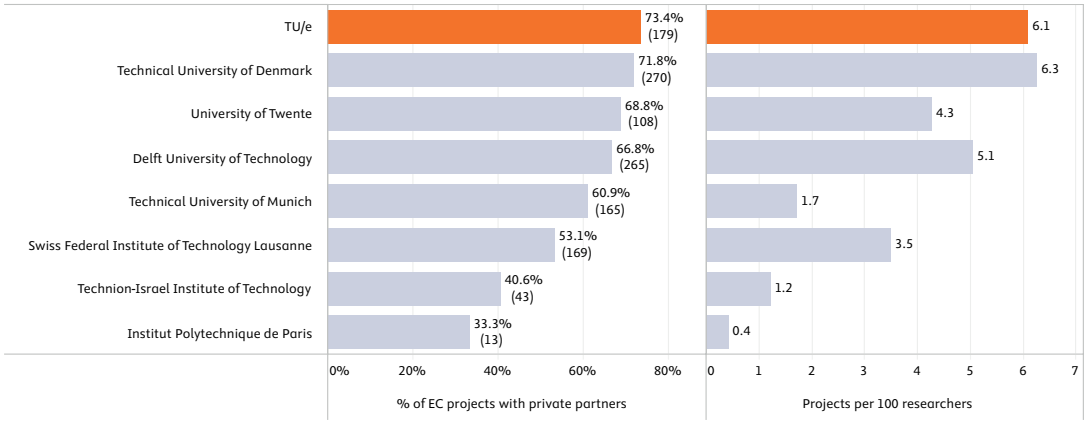


Figure 10

Left: *Share of EC-funded projects with private partners that started from 2018–2022. The absolute number of projects with private funders is shown in brackets.* ***Right:*** *Number of projects with private partners per 100 researchers.*

Source: CORDIS/Scopus

Over 60% of EC funding awarded to TU/e for projects starting from 2018–2022 was for projects with private sector involvement, placing TU/e alongside two other Dutch benchmarks and the Technical University of Denmark, with a similarly significant amount of related funding (***Figure 11***). When adjusted for the average number of active researchers during the reference period, TU/e places second in terms of the funding amount received for projects involving private partners.

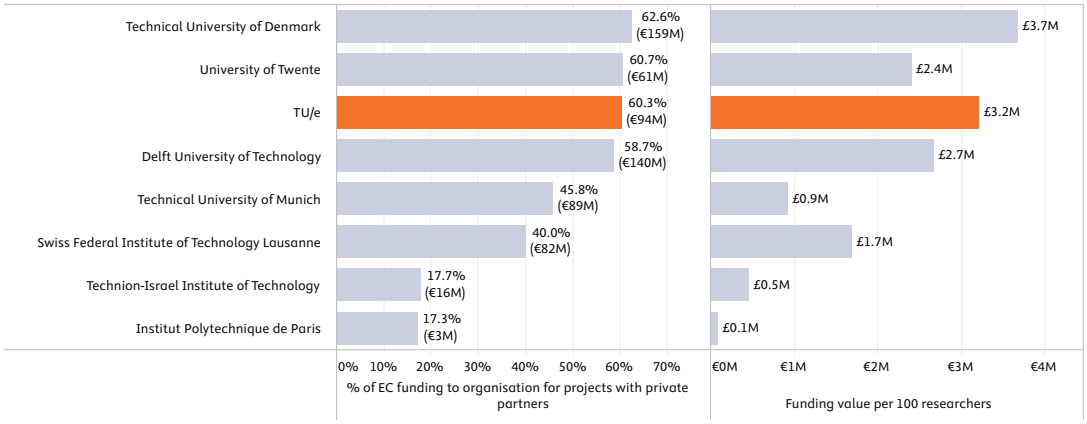


Figure 11

Left: *Share of EC funding to organizations for projects with private partners, which started from 2018–2022. The absolute value is shown in brackets.* ***Right:*** *Funding to organizations for projects with private partners per 100 researchers.*

Source: CORDIS/Scopus

The geographic proximity of the universities to the local knowledge and innovation ecosystem plays a clear role in forging partnerships within EC-funded projects. While most TU/e projects with the private sector involved private partners located beyond the 75 km radius, 37% of projects also involved a total of 47 private partners located within the 25 km radius (***Figure 12***).

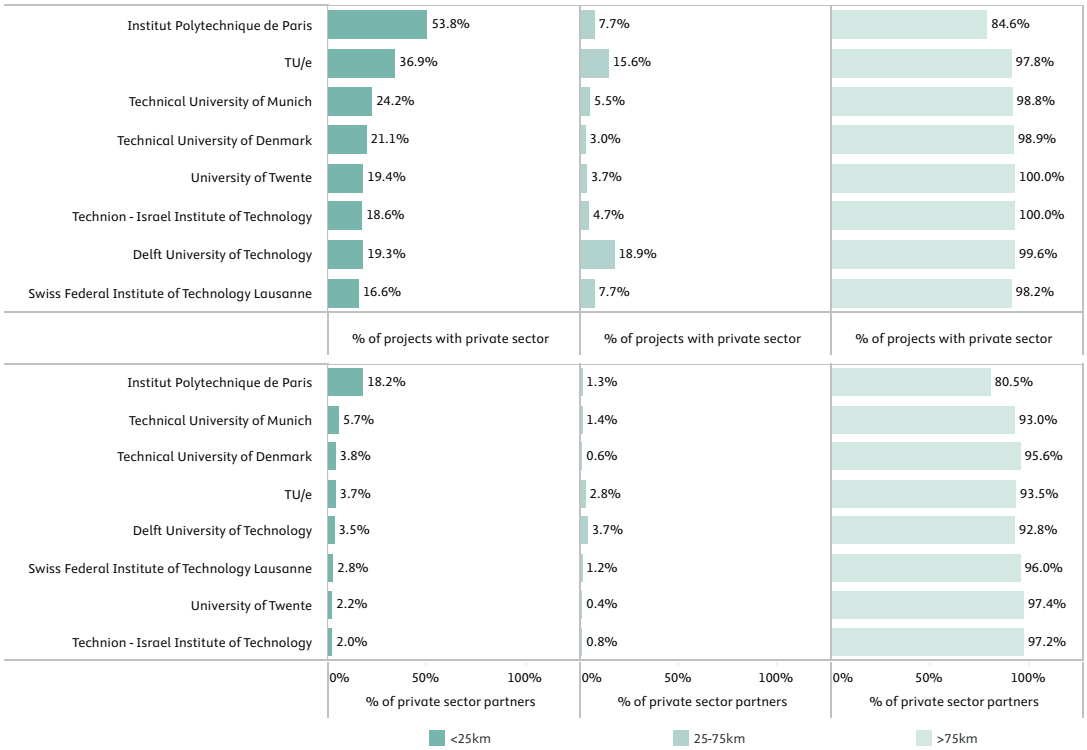


Figure 12

***Top**: Share of EC projects with private partners by distance between the university and the partners. Note that a single project can be classified into multiple distance categories due to the involvement of partners at varying distances. Therefore, the bars may not add up to 100%. Universities are sorted based on the share of projects with partners within a 25 km radius from the university. **Bottom**: Share of unique private partners by distance between the university and partners. As opposed to publications, each collaborator is assigned to only one category. Universities are sorted based on the share of partners within a 25 km radius from the university.*

Source: CORDIS

TU/e's partnerships with local industrial entities located within the 25 km radius, including NXP Semiconductors, Philips, and SMART Photonics BV—a spin-off from TU/e focused on photonic components—underline its crucial influence in establishing a dynamic innovation ecosystem (***Figure 13***). The collaboration with SMART Photonics highlights TU/e's ability to maintain fruitful ties with its spinout companies. Moreover, the technology area of photonics is acknowledged by both the EU and the Dutch government as strategically vital, thereby highlighting TU/e's contribution to supporting ecosystem players and fostering advancements in this critical field.

These partnerships and their close proximity to the university exemplify the importance of innovation ecosystems. Through maintaining a regional focus, such partnerships enable value creation with a global impact.

Institution Name	Collaborator	Projects	EC funding to university	Total EC funding
TU/e	NXP Semiconductors B.V.	12	€5.80M	€100.5M
	Philips Electronics B.V.	10	€6.04M	€106.2M
	Smart Photonics B.V.	8	€7.16M	€74.2M
Technical University of Denmark	NKT Photonics A/S	5	€3.46M	€22.0M
	Norblis ApS	4	€3.74M	€26.7M
	Enfor A/S	4	€3.15M	€44.5M
Technical University of Munich	Siemens AG	5	€5.54M	€58.5M
	Concentris Research Management GmbH	3	€1.47M	€33.2M
	ARTTIC Innovation GmbH	3	€2.42M	€28.3M
Swiss Federal Institute of Technology Lausanne	LIGENTEC SA	5	€2.30M	€32.0M
	Cyberbotics SARL	3	€17.79M	€263.0M
	MicroR Systems Sarl	2	€0.83M	€6.0M
University of Twente	Thales Nederland B.V.	4	€2.43M	€12.1M
	LioniX International B.V.	4	€2.48M	€16.2M
	Solmates B.V.	3	€1.69M	€52.6M
Delft University of Technology	Anywi Technologies B.V.	4	€1.09M	€44.0M
	Innatera Nanosystems B.V.	3	€0.72M	€33.6M
	Technolution B.V.	3	€1.58M	€18.2M
Technion - Israel Institute of Technology	Mellanox Technologies Ltd	4	€0.79M	€262.0M
	Technion Research & Development Foundation Ltd	1	€1.25M	€4.0M
	Minovia Therapeutics	1	€0.00M	€2.6M
Institut Polytechnique de Paris	Thales LAS France SAS	1	€0.03M	€7.0M
	Thales	1	€0.17M	€3.3M
	Storengy SAS	1	€0.00M	€5.0M

Figure 13

Top 3 corporate partners within 25 km from university within EC-funded projects with university participation. The table shows 1) overall number of projects with the private sector partner 2) value of EC funding received by university for the projects 3) total value of EC funding awarded to the projects.

Source: CORDIS

5. Alignment with key enabling technologies

Key enabling technologies (KETs) provide a window into the technological innovation potential of an ecosystem. TU/e has a high share of output in KETs with an above-the-average citation impact and strong specialization in most KET families.

Why is this important?
Key technologies jointly prioritized by government and industry are an important signal of future relevance and available funding.

How is it measured?
Academic papers are classified into eight key technology families of the Dutch key technology framework. The benchmarks are analyzed for specialization and citation impact in these critical areas.

Aligning with key enabling technologies (KETs) is essential for 4th generation universities with a focus on technology to effectively contribute to societal and economic advancements. By integrating these technologies into their research agendas, universities ensure their work is at the cutting edge, addressing vital sectors poised to shape future economies and societies. This focus enables universities to lead in developing solutions with broad industrial applications, enhancing their regional and global innovation impact.

While our analysis leverages the Dutch KET framework, the underlying principles and technology priorities are globally relevant, making our findings applicable to universities worldwide. The global emphasis on key technologies illustrates the potential for insights derived from the analysis to shape strategies enhancing the role of universities in innovation ecosystems worldwide. This shared focus on such technologies lays a robust groundwork for comparison, emphasizing KETs as a strategic priority for universities aiming to drive forward sustainable and innovative societies, incorporating perspectives from universities across different countries.

This section's analysis is based on eight key technology families, as outlined by the Dutch Ministry of Economic Affairs and Climate Policy, with contributions from TNO and NWO. These families include 44 technologies listed in the Annex. A recent Elsevier report, commissioned by the Dutch Ministry of Economic Affairs and Climate Policy[10], developed search queries to define these key enabling technologies.

10 Elsevier (2024). Quantitative analysis of Dutch research and innovation on key technologies

These queries are applied here at the technology family level. The technology families covered are:

- Advanced materials
- Photonics and optical technologies
- Quantum technologies
- Digital and information technologies
- Chemical technologies
- Nanotechnology
- Life sciences and biotechnologies
- Engineering and manufacturing technologies

Although TU/e's overall output in key enabling technologies may not match the volume of larger institutions in the comparator group, it has a strong performance in terms of the proportion of its research focused on these critical areas (***Figure 14***). Nearly 60% of TU/e's total institutional output is dedicated to key technology research, placing it at the forefront by this measure. TU/e's field-weighted citation impact in key enabling technologies is also higher than the World average of 1.0, although key technology research conducted by the Swiss Federal Institute of Technology Lausanne and Technical University of Munich emerges as the most impactful among the comparators.

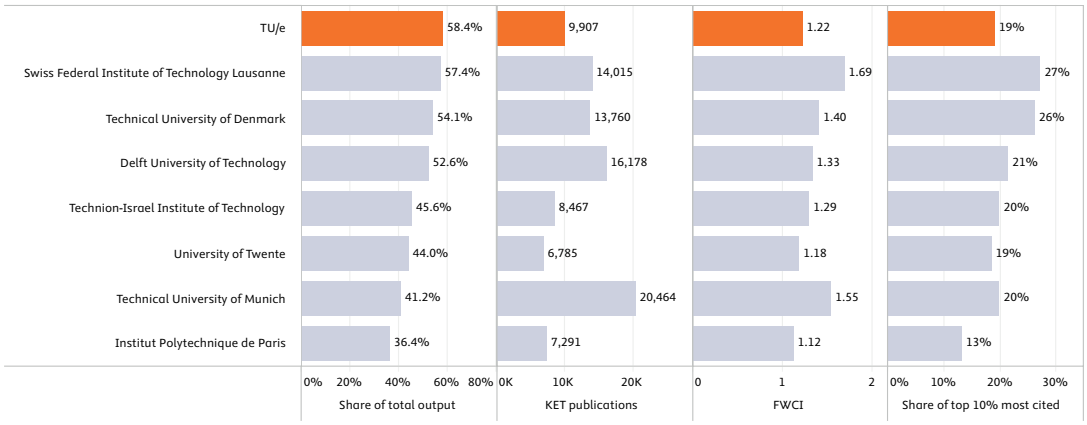


Figure 14

TU/e's and comparators' relative positions in scholarly output addressing key enabling technologies. The chart shows 1) Share of publications in key enabling technologies relative to total institutional output. The institutions are sorted according to this indicator 2) Total number of publications on key enabling technologies 3) Field-weighted citation impact, with the world average level set at 1.0. 4) Share of KET publications in top 10% most cited publications worldwide.

Source: Scopus

The comparators exhibit different levels of specialization across various technology families, assessed using the relative activity index (RAI). This indicator evaluates an institution's share of output in a specific technology family against the global share in the same family. With the global average set at 1.0, values above 1.0 signify a specialization level exceeding the global average.

Compared to its peers, TU/e is highly specialized in Engineering and Fabrication Technologies, Digital and Information Technologies, Photonics and Optical Technologies and

Advanced Materials (***Figure 15***). Most comparators surpass the global RAI average across key technology families.

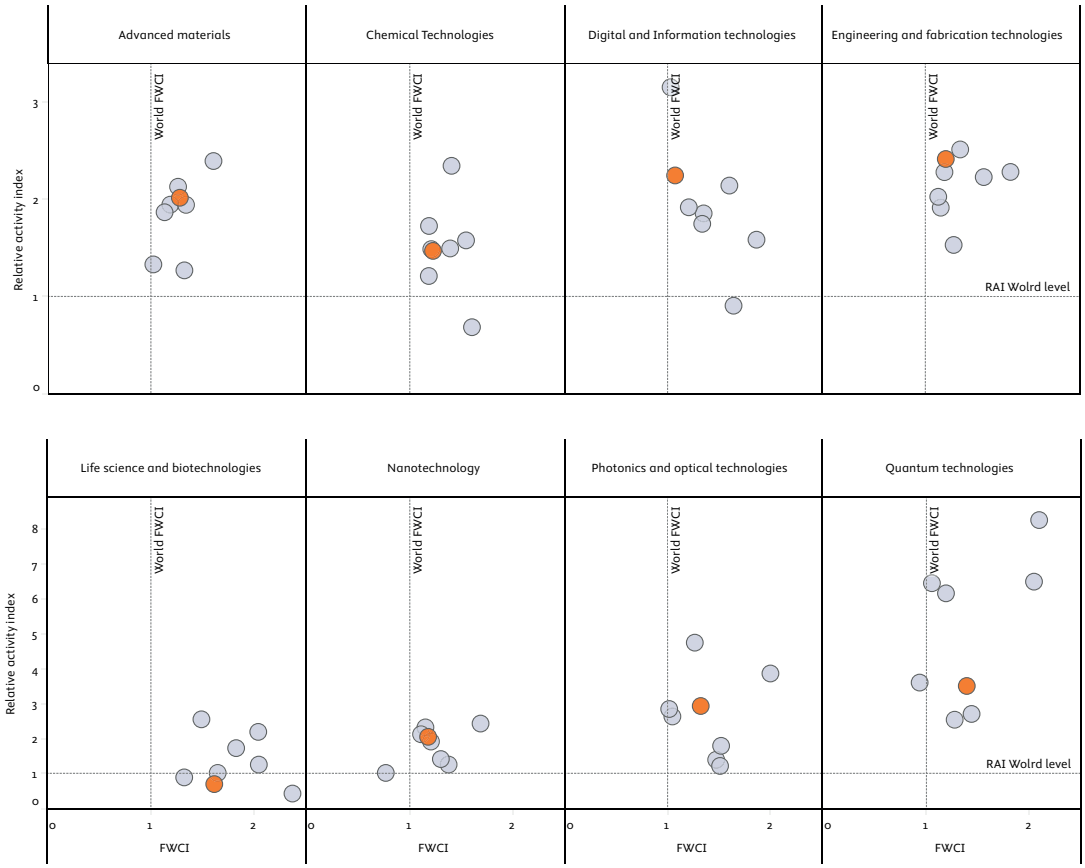


Figure 15

Relative activity index (specialization) and field-weighted citation impact of TU/e (orange) and comparators in key technology families (2018–2022).

Source: Scopus

To capture a more dynamic picture of the universities' alignment and performance in key technology families, the figure below reflects the developments in output and citation impact from 2018 to 2022. To achieve this, we first calculate the year-on-year growth over the reference period for each institution in each technology family. Next, to provide a holistic measure of growth, we calculate the average growth rate across the period for each institution and technology family.

It should be noted that this type of analysis highlights a complex relationship between output production and citation impact (quality vs. quantity). In some cases, increased output from high-quality research groups may maintain or even increase citation impact, while in others, rapid increases in publication quantity without corresponding quality can dilute citation impact. Each scenario can vary significantly across different disciplines, institutions, and over time.

TU/e has experienced a notable positive growth dynamic in output in such KETs as Digital and Information Technologies, Life Science and Biotechnologies, and Quantum Technologies, while at the same time experiencing a slight or moderate decline in citation impact. The only KET for which TU/e's citation impact has been on the rise is Photonics and Optical Technologies, although its output production in this area has been mostly stable with a slight decrease.

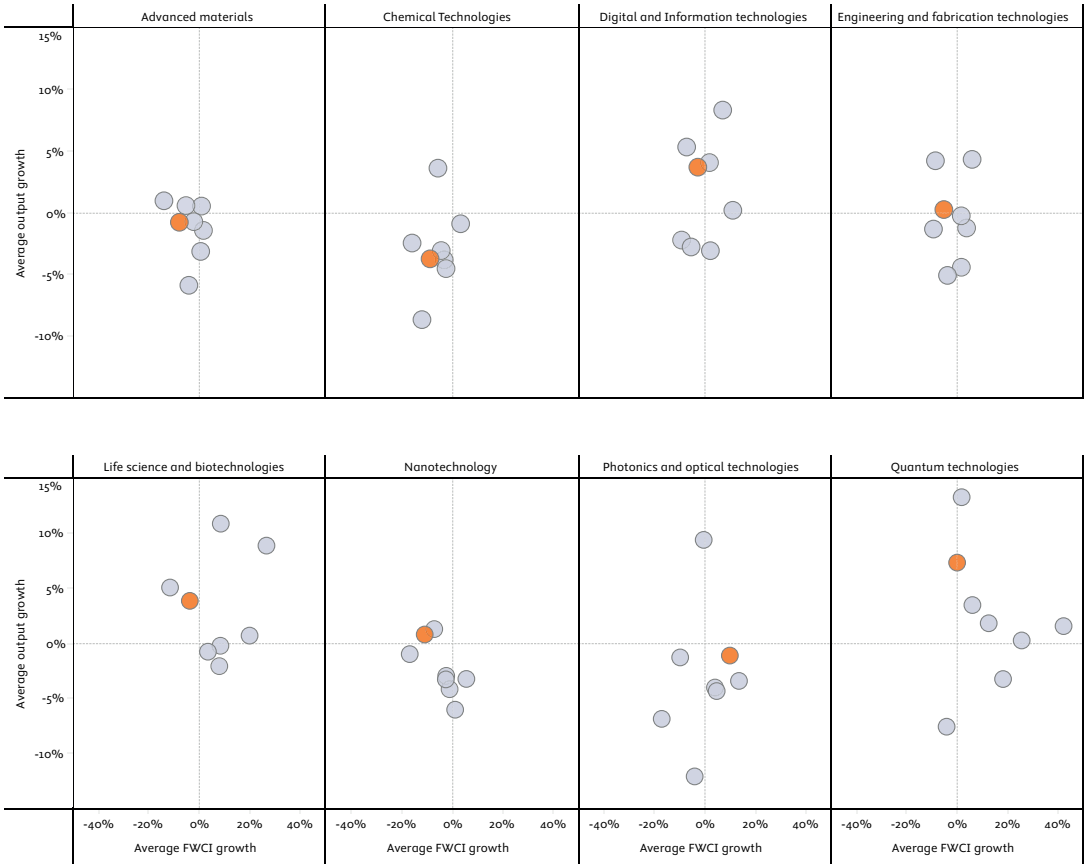


Figure 16

Average year-on-year output and field-weighted citation impact growth for TU/e and comparators in each key technology family from 2018 to 2022.

Source: Scopus

6. Patent co-ownership with industry

Patent co-ownership analysis reveals TU/e's efforts to translate academic research into practical, market-oriented outcomes, albeit with scope for further enhancement, particularly in the overall size, global technology relevance and market coverage of its patent portfolio co-owned with corporate partners.

Why is this important?
Joint ownership of intellectual property with industry partners ensures long-term commercial benefits of innovation and alignment of research with market demands.

How is it measured?
Capturing and analyzing patent families jointly owned by the benchmarks and industrial partners.

In the analysis of university–industry collaborations, patent co-ownership stands as another critical indicator for assessing the depth and efficacy of partnerships between academia and the private sector. This analysis explores the size, technology relevance and market coverage of patents co-owned by the benchmark universities in conjunction with at least one corporate entity.

Patent co-ownership is not merely a legal arrangement; it reflects a shared commitment to advancing research and development, by translating academic discoveries into market-ready innovations. Incorporating indicators such as technology relevance and market coverage into this analysis illuminates the depth and breadth of these partnerships.

- **What is technology relevance?** Determined by the frequency and context of citations received by analyzed patents from subsequent patents, technology relevance reveals the extent to which co-owned patents influence subsequent technological advancements. It reflects the significance of these patents in their respective fields, indicating their role as foundational elements upon which future innovations are built.

- **What is market coverage?** This indicator evaluates the commercial potential of these innovations by assessing the geographical expanse over which the patents are protected. It provides an estimation of the global market reach of the patented technology, benchmarked against the size of the United States market, the world's largest national market. This measure hints at the strategic importance placed on securing patent rights in various international jurisdictions, thereby underlining the economic aspirations tied to these collaborative efforts.

Together, these indicators enrich our understanding of patent co-ownership by highlighting not only the collaborative nature of these partnerships but also their strategic intent and potential impact on global innovation and markets.

The patent portfolio of TU/e, comprising patents published from 2018–2022, includes 15 patent families that are co-owned together with industrial partners (***Figure 17***). This figure is comparatively smaller than the industry co-owned portfolios of several of TU/e's peers, even when adjusted for the volume of TU/e's academic output. The normalization partially accounts for variations in institutional size, which can be presumed to correlate with the capability to generate patentable innovations.

It should be noted that patent ownership has not been an area of focus for TU/e, with the university mainly driving its commercialization efforts through start-ups and spinouts. This strategic focus explains the comparatively low numbers. In terms of technology relevance and market coverage, TU/e's portfolio also ranks in the middle of the peer group.

With respect to other comparators, Technion-Israel Institute of Technology has the biggest portfolio size when normalized by total scholarly output. Delft University of Technology stands out for having the most technologically relevant patents, and Technical University of Denmark boasts the highest market coverage score, highlighting its extensive commercial reach.

	Portfolio Size per 1000 Publications	Portfolio Size	Market Coverage	Technology Relevance
Technion-Israel Institute of Technology	2.0	38	1.56	1.16
Swiss Federal Institute of Technology Lausanne	1.3	31	1.37	0.97
Technical University of Munich	1.0	51	1.31	1.34
TU/e	0.9	15	1.43	1.20
Technical University of Denmark	0.9	22	1.79	1.34
Institut Polytechnique de Paris	0.8	17	1.55	0.81
University of Twente	0.7	11	0.84	1.97
Delft University of Technology	0.5	14	1.48	4.00

Figure 17

Patent portfolio co-owned by the university and at least one corporate partner for patents with a publication date from 2018–2022. The table shows 1) Patent portfolio size normalized per 1,000 scholarly publications 2) Portfolio size 3) Portfolio market coverage 4) Portfolio technology relevance. The organizations are sorted based on normalized portfolio size.

Source: PatentSight/Scopus

Although the size of TU/e's patent portfolio co-owned with corporate partners is modest, there are some organizations with which TU/e holds multiple patent families, including Philips, Thornhill Research and TBI Innovations LLC (***Figure 18***). Not surprisingly, out of these three partnerships the one with Philips has the highest market coverage and technology relevance.

Institution Name	Corporate co-owner	Portfolio Size	Market Coverage	Technology Relevance
Technical University of Munich	BMW	14	0.46	0.92
	Huawei	6	2.09	1.73
	Nokia	3	2.82	1.02
Institut Polytechnique de Paris	TotalEnergies	12	1.64	0.72
	Air Liquide	6	1.58	0.61
	Dassault Systemes	2	1.99	0.97
Technion-Israel Institute of Technology	StemCells Inc.	6	1.43	3.40
	Technion Research Development Foundation Ltd	5	1.72	0.68
	IBM	4	0.92	0.28
Delft University of Technology	Applied Materials Ltd	6	1.73	7.93
	Intel	4	1.21	1.47
	CrossWind	1	2.11	1.52
Swiss Federal Institute of Technology Lausanne	ONWARD Medical B.V	6	1.40	0.76
	TotalEnergies	3	0.99	0.41
	Valeo	2	2.72	0.97
Technical University of Denmark	Hamamatsu Photonics	3	1.89	0.16
	Sony	2	2.56	0.48
	Aquagreen License ApS	2	2.16	1.35
TU/e	Philips	3	1.81	1.17
	Thornhill Research Inc	2	0.70	0.81
	TBI Innovations LLC	2	0.70	0.81
University of Twente	Shenzhen Guohua Optoelectronics Technology Co., Ltd	5	0.71	1.13
	LioniX International BV	1	1.91	2.93
	ASM International	1	1.42	8.21

Figure 18

Top 3 corporate co-owners of universities' patent portfolios, comprising patents with a publication date from 2018–2022. The table shows 1) The size of portfolio co-owned with a given corporate entity 2) Portfolio market coverage 3) Portfolio technology relevance.

Source: PatentSight

7. Knowledge utilization by industry

Academic knowledge produced by TU/e and other benchmark universities contributes to the development of patented technology, hinting at a wider impact of academic research on practical applications.

Why is this important?
Contributions to the creation of corporate intellectual property showcase the broader economic and technological influence of universities.

How is it measured?
Global corporate-owned patents citing universities' academic papers are analyzed for volume, technology relevance and market coverage.

By examining patent families that cite academic research published by the benchmark universities, further insights can be gained into how scholarly work fuels industrial innovation and development. The analysis focuses on three critical dimensions: portfolio size, which indicates the volume of industry patents drawing on academic research; technology relevance, reflecting the impact and influence of cited academic work within specific technology fields; and market coverage, revealing the commercial breadth and geographical spread of these innovations that draw on academic work.

To account for differences in the size of the institutions, patent citations and citing patents in this analysis are normalized per 1,000 scholarly publications. TU/e's influence on technological innovation as measured by the utilization of its research in patents places it in the middle of the comparator group (***Figure 19***). The highest values across all patent citation indicators are demonstrated by Swiss Federal Institute of Technology, testifying to the extensive utilization of this institution's research in innovation settings.

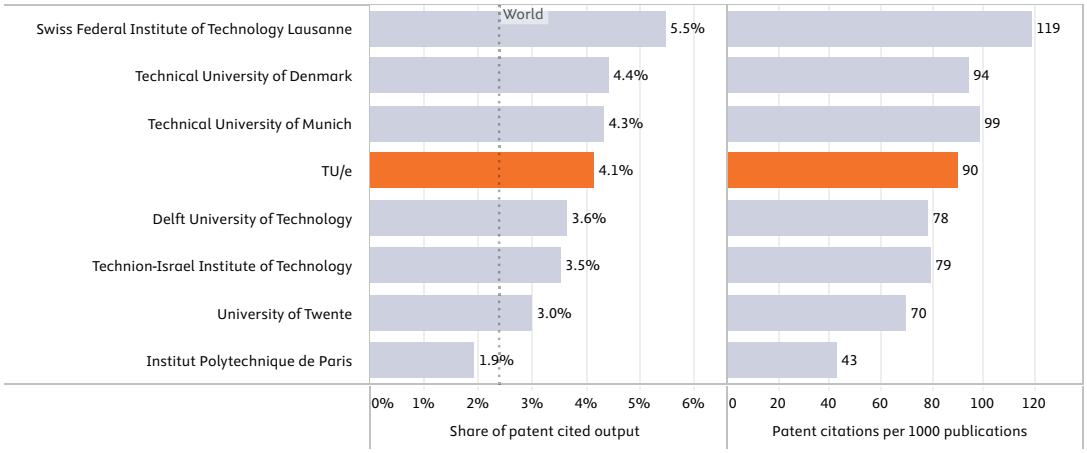


Figure 19

Left: *Share of scholarly output with patent citations in 2018–2022.* ***Right:*** *Number of patent citations per 1,000 scholarly publications. The institutions are sorted according to the share of patent-cited output.*

Source: Scopus/PATSTAT

Several corporate organizations emerge as the most prolific users of scholarly research published by benchmark universities. For TU/e, the biggest citing organizations are ASM International, Microsoft and Philips. Notably, many of the same tech giants appear among the users of academic research coming from various comparators, which suggests that the comparators' research is highly relevant for the cutting-edge technology patented by the mentioned companies.

Institution Name	Owner	Portfolio Size	Market Coverage	Technology Relevance
University of Twente	ASM International	232	1.51	18.73
	Curious	7	1.00	2.38
	Philips	7	1.80	0.73
TU/e	ASM International	170	1.54	19.83
	Microsoft	16	2.05	1.22
	Philips	22	2.29	1.16
Institut Polytechnique de Paris	ASM International	149	1.55	20.51
	Magic Leap	15	2.04	1.83
	Nokia	15	1.63	1.60
Delft University of Technology	10x Genomics	87	1.99	11.99
	IBM	41	1.80	0.87
	Microsoft	35	2.09	1.52
Swiss Federal Institute of Technology Lausanne	IBM	76	1.61	1.06
	Microsoft	34	1.88	1.33
	Samsung	28	1.76	1.97
Technical University of Munich	Roche	37	2.39	2.03
	Siemens	40	1.73	0.98
	Unilever	36	2.63	0.93
Technical University of Denmark	Microsoft	23	2.18	1.13
	State Grid Corp	17	0.72	1.80
	Vor Biopharma Inc	16	1.99	1.17
Technion-Israel Institute of Technology	10x Genomics	21	1.70	11.44
	IBM	19	1.46	1.78
	Microsoft	17	2.23	1.20

Figure 20

Top 3 corporate owners of patent families citing scholarly research from benchmark universities published in 2018–2022.The table shows 1) The size of portfolio of patent families citing scholarly research 2) Portfolio market coverage 3) Portfolio technology relevance.

Source: PatentSight

8. Spinouts and alumni-founded companies

Nearly 90% of TU/e's spinouts and 48% of alumni-founded companies are situated within 75 km of the university, underlining TU/e's impact on the local innovation ecosystem and cultivation of entrepreneurial spirit.

Why is this important?
Transferring knowledge through the creation of new companies provides a positive contribution to the local economic development.

How is it measured?
University spinouts and alumni startups are analysed through the lens of geographic proximity to the university.

Examining spinouts and alumni-founded start-ups provides additional insights into universities' contribution to innovation ecosystems. University spinouts, in particular, play a crucial role in transforming the knowledge and innovations developed within academic institutions into commercially viable entities, contributing significantly to the creation of a vibrant knowledge and innovation ecosystem around universities.

Spinouts serve as a primary mechanism for the commercialization of university research, turning intellectual property into products, services, and technologies that address societal needs and challenges. They also contribute to local and regional economic development by generating employment, attracting investment, and stimulating the growth of related industries.

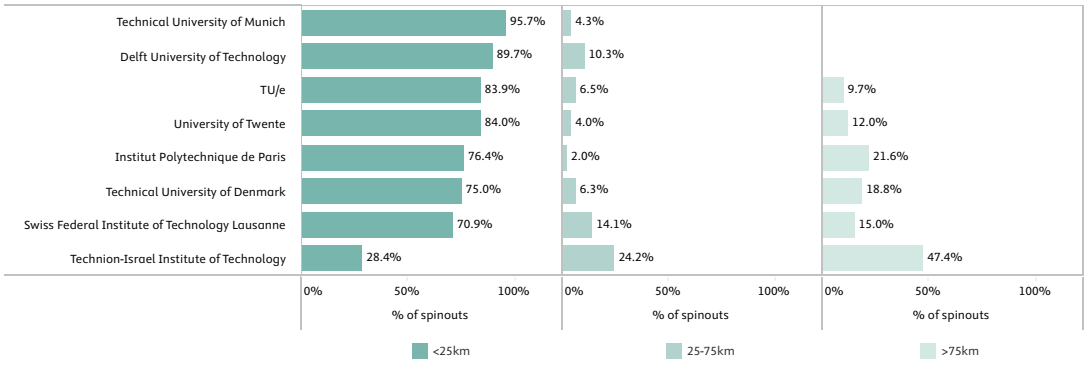


Figure 21
Share of spinout companies by distance from the university (2013–2022).

Source: Dealroom

Spinouts located close to the university typically enrich the local innovation ecosystem through direct collaboration and knowledge exchange, enhancing the immediate area's economy. Those further away, especially beyond 75 km, demonstrate the broader reach of university innovation, potentially influencing broader national and international markets. This approach underscores the university's role in fostering economic growth at multiple levels, from local to international. Furthermore, university spinouts that establish themselves closer to the university are usually those that are found to have more aggressive strategies and technological demands, while those that move further away do so to pursue new markets.[11]

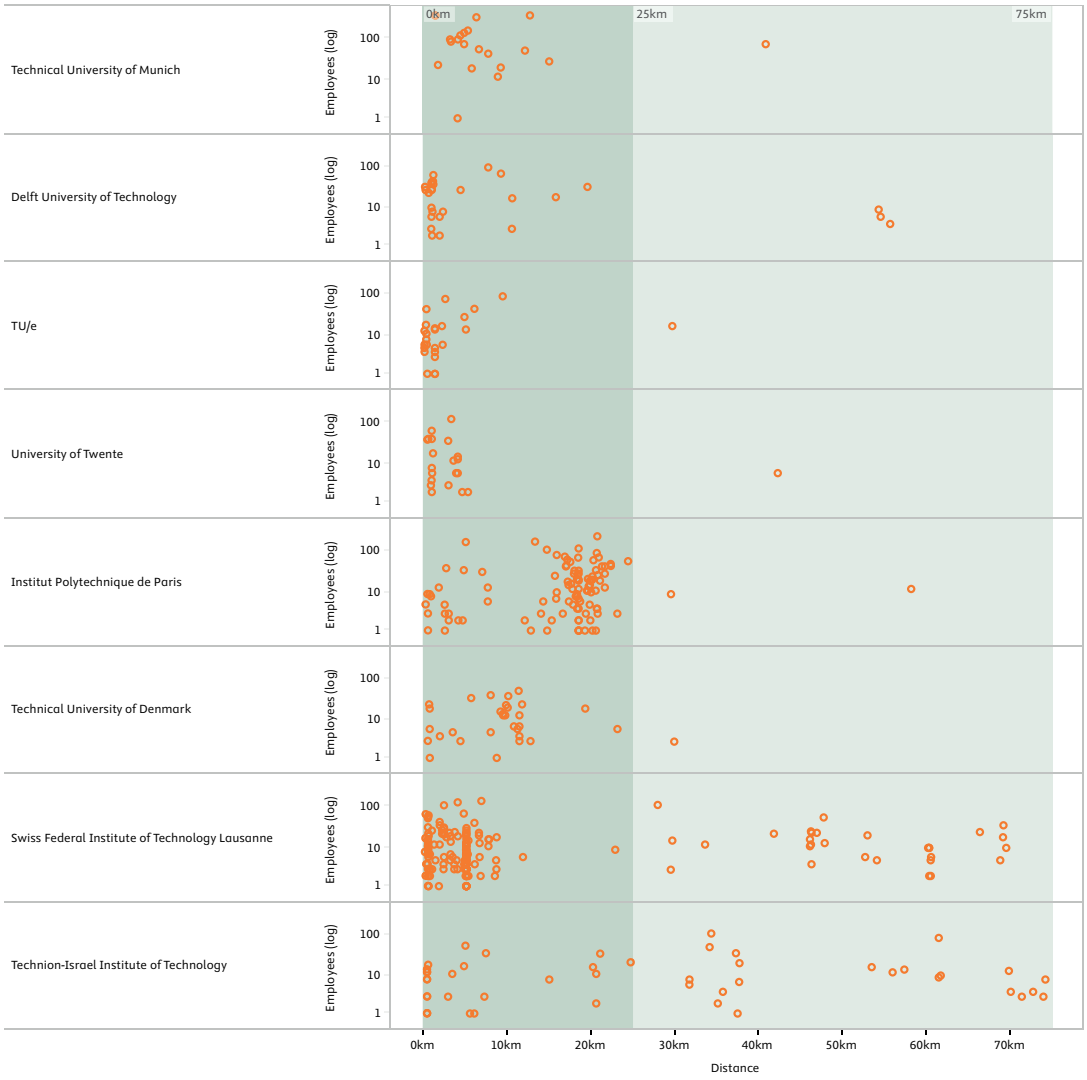


Figure 22

Distribution of spinout companies by distance (horizontal axis) from the university and latest number of employees (log vertical axis). Note that several companies, for which employee data was unavailable were excluded.

Source: Dealroom

11 Berchicci et al. (2011). Does the apple always fall close to the tree? The geographical proximity choice of spin-outs.

The majority of TU/e spinouts founded in 2013–2022 are located remarkably close to the university—within the 25 km radius (***Figure 23***). Most are concentrated in the municipality of Eindhoven, although there are also some companies headquartered in the surrounding municipalities of Helmond (Lightyear, a company working on solar layers for the mobility sector) and Son en Breugel (robot-assisted microsurgery manufacturer Microsure). This exemplifies the inclusion of the broader region around Eindhoven into the Brainport ecosystem.

Figure 23
Bottom: *Distribution of TU/e's spinout companies by distance (log horizontal axis) from the university and latest number of employees (log vertical axis). Note that several companies, for which employee data was unavailable, were excluded.* ***Top right:*** *Geographical representation of TU/e's spinout companies located within 25 km and 75 km of TU/e.* ***Top left:*** *Geographical representation of TU/e's spinout companies in the immediate proximity of TU/e.*

Source: Dealroom

As opposed to spinouts, alumni-founded companies are not necessarily born from academic research and university projects, but they reflect the entrepreneurial skills and knowledge

imparted during university education. This highlight universities' broader role, not only as incubators of research-based enterprises but also as key players in shaping entrepreneurial talent.

The proximity of these start-ups to their universities reveals their impact on local and broader innovation landscapes. Start-ups near universities directly benefit from and contribute to the local ecosystem, accessing resources and fostering a community that bolsters regional development.

Meanwhile, those located farther away demonstrate the university's influence on wider scales, contributing to innovation ecosystems beyond their immediate surroundings and highlighting the global reach of their alumni network. This distribution reflects the university's comprehensive impact: nurturing a dense local innovation ecosystem while also influencing broader entrepreneurial activities. It emphasizes the role of universities in driving economic development and innovation on a global scale through their alumni.

Over 30% of TU/e alumni-founded companies are located within 25 km from the university with another 18% being within 25–75 km (***Figure 24***). Outside of this area, most of the remaining start-ups are headquartered in the Netherlands, although the overall geographic diversity TU/e alumni founded companies covers multiple continents and countries.

From these figures, various profiles emerge. Technical University Denmark boasts the highest proportion of alumni-founded companies located within 25 km of the institution, with over 55% of such start-ups situated in this proximity range. Notably, Delft University of Technology also shows a significant concentration close to the university, with more than 60% of its alumni-founded start-ups within a 75 km radius. Both Technion-Israel Institute of Technology and University of Twente combine an alumni-driven impact in the local ecosystem with a strong reach far beyond their regional boundaries.

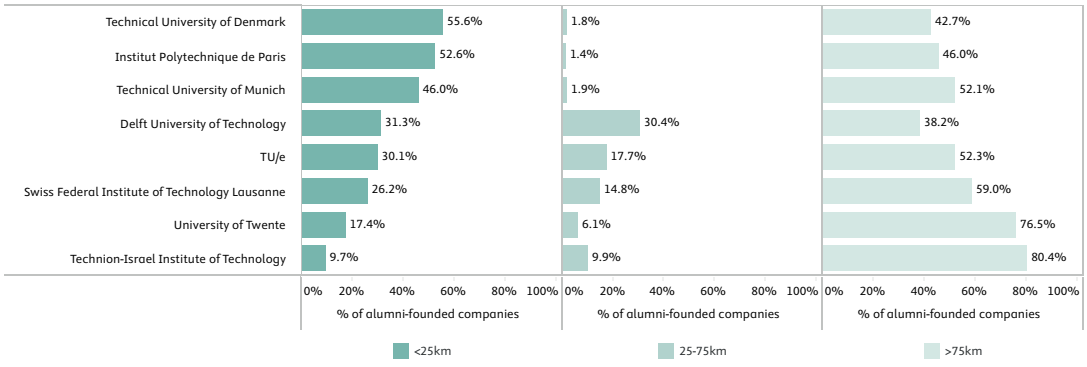


Figure 24
Number of alumni-founded start-ups by distance from the university (2013–2022).

Source: Dealroom

The granular geographical distribution of alumni-founded companies shown in ***Figure 25*** and ***Figure 26*** reveals a series of unique preferred locations where start-ups tend to be situated. For TU/e, distinctive, but varying in size clusters emerge within 75 km in places like Eindhoven, 's-Hertogenbosch, Nijmegen, Breda, Maastricht, and Utrecht.

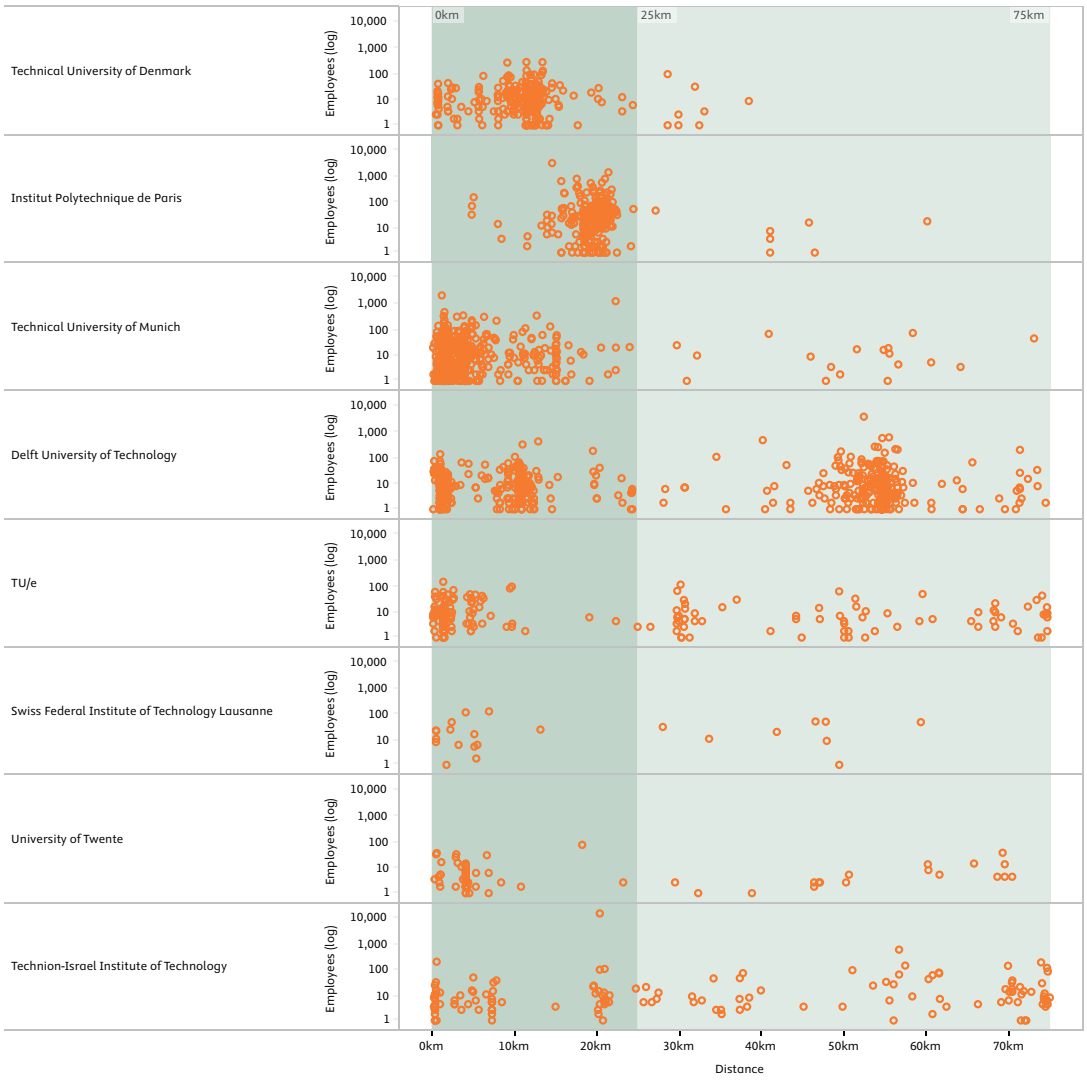


Figure 25

Distribution of university alumni-founded start-ups by distance (horizontal axis) from the university and latest number of employees (log vertical axis). Note that several companies, for which employee data was unavailable, were excluded.

Source: Dealroom

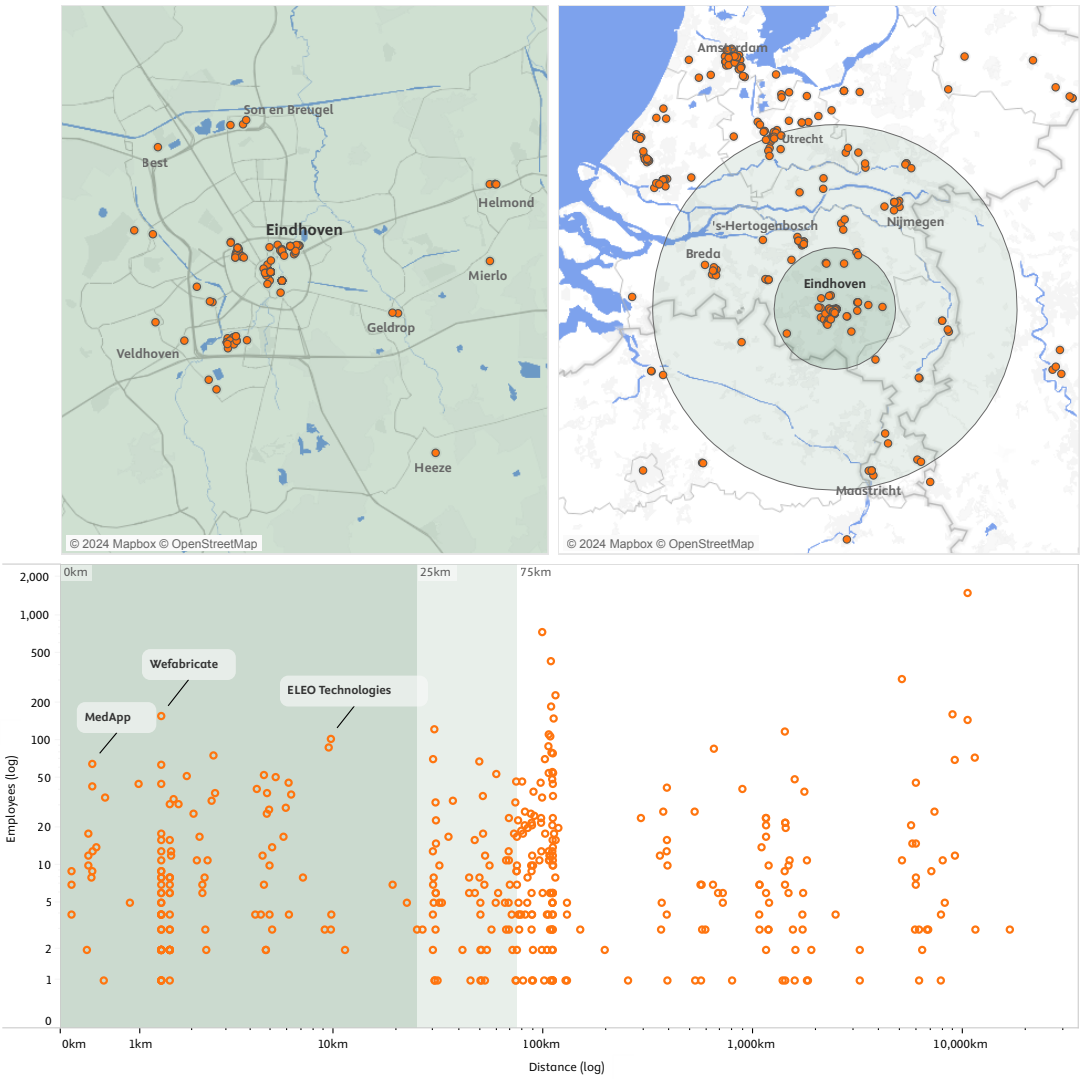


Figure 26

Bottom: *Distribution of TU/e's alumni-founded start-ups by distance (log horizontal axis) from the university and latest number of employees (log vertical axis). Note that several companies, for which employee data were unavailable were excluded.* ***Top right:*** *Geographical representation of TU/e's alumni-founded start-ups located within 25 km and 75 km of TU/e.* ***Top left:*** *Geographical representation of TU/e's alumni-founded start-ups in the immediate proximity of TU/e.*

Source: Dealroom

9. Shaping the innovation ecosystem

TU/e is a strong driver of the Brainport Eindhoven ecosystem, blending leadership, partnerships, and global engagement to nurture a vibrant innovation landscape.

Measuring progress toward the 4th generation university model is a complex and multifaceted task, particularly when it comes to assessing the university's broader engagement with the ecosystem. Capturing the full extent of these engagements and their impact presents several challenges, such as the diversity of engagements, intangible outcomes (the development of trust, social capital, and shared visions among stakeholders) and attribution of outcomes to the university. These challenges make it difficult to develop a comprehensive and consistent set of metrics for assessing progress.

To mitigate these challenges, a further framework can be developed to capture additional information about the university's engagement with the ecosystem. An example framework can include the following dimensions, which universities can contribute information on:

SOURCE: BART VAN OVERBEEKE

Dimension	Analysis
Ecosystem leadership	• The role of the university in regional strategy-setting platforms and organizations.
Co-creation platforms	• Participation or membership of the university in co-creation programs • Participation of the university in joint regional knowledge and innovation platforms: campuses, open thematic networks.

Partnerships	• Strategic long-term and formalized collaborations with a specific focus, in three categories:
	  • with companies on specific R&D/societal challenges
	  • with societal organizations on specific R&D/societal challenges
	  • sponsored professorships and cross-appointments

Knowledge infrastructures	• Joint or shared R&D and education facilities with industry, societal partners and/or regional educational partners, e.g. labs, pilot plants, living labs.
Capital facilities	• Regional funding programs to stimulate value creation with knowledge partners and entrepreneurship based on research and education results, e.g. regional innovation funds, venture capital.
Cultural embedding	• Participation of the university in programs aimed at enhancing the social fabric of the ecosystem, e.g. spouse programs, international community, community service.
International network	• International networks of innovation ecosystems that the university and/or the ecosystem organizations participate in.

Table 3
Proposed framework for the assessment of university's contribution to ecosystem governance.

While information across these dimensions is not available for benchmarks in this report, we showcase TU/e's engagement with the Brainport Eindhoven ecosystem, a thriving innovation hub in the region. Home to a dense network of tech companies, research institutions, and startups, Brainport is known for expertise in semiconductors, photonics, and design. The ecosystem fosters creativity and entrepreneurship, with strong academia-industry collaboration driving advancements in fields like advanced manufacturing, robotics, and smart mobility. Emphasizing sustainability and societal impact, Brainport Eindhoven continually pushes technological boundaries and supports regional and global economic growth.

Brainport is known for its concentration of technology-oriented businesses, particularly in fields such as electronics, semiconductor manufacturing, photonics, and advanced materials. Large multinational corporations like ASML, Philips, and NXP Semiconductors have a significant presence in the area, along with numerous SMEs and startups operating in various high-tech sectors. With approximately 30,000 companies in economic priority sectors, industry in the Brainport ecosystem invests around €3 billion in R&D and delivers some 3,500 patents annually. TU/e's organized engagements with Brainport are summarized as follows:

SOURCE: BART VAN OVERBEEKE

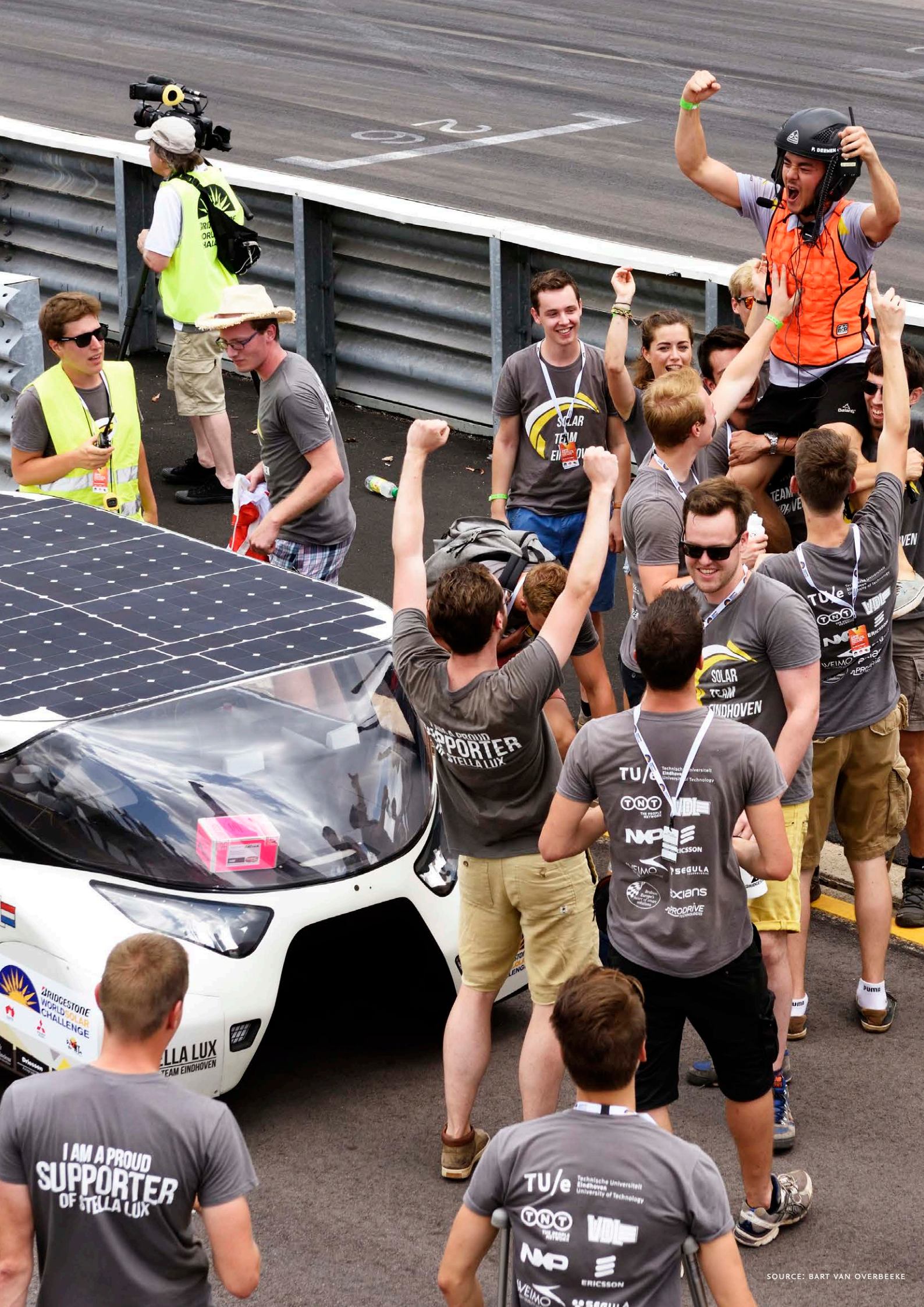
Dimension	TU/e contributions
Ecosystem leadership	• The Brainport foundation is the strategy-setting organization in the Brainport region, with Brainport Development as its main executive agency. TU/e is member of the foundation board, alongside 4 majors, 4 knowledge institutions and 6 large industry partners.
Co-creation platforms	• The TU/e Campus is one of five major campuses, alongside the High Tech Campus, the Brainport Industries campus (SMEs), the Automotive Campus and the Strijp-S Campus. • TU/e is founding father of the Brainport one-stop-shop for start-ups and early-stage entrepreneurs organization The Gate and the co-creation for innovation platform Eindhoven Engine • In the TU/e Innovation Space, around 50 student teams work on innovations, including students from Fontys and Summa (vocational higher education). • TU/e participates in several national innovation programs with a strong focus on Brainport, such as PhotonDelta, Battery Competence Cluster, and Semicon competence centre, among others.

Partnerships	• TU/e has formalized partnerships in category A (companies):
	  • Formalized partnerships with ASML, NXP and Thermo Fisher;
	  • Framework agreements with SHELL and several other companies.

Knowledge infrastructures	• TU/e participates in several living labs and pilot plants, such as the Stratumseind living lab (security) and the Brightlands pilot plant (chemistry) as part of the Chemelot Institute for Science and Technology (InSciTe) program.

Capital facilities	• Within Brainport, many funding facilities are available for start-up companies and high-tech entrepreneurs, such as (selection):
	  • Monthly funding roundtable;
	  • Brabant start-up fund;
	  • Metropole Region Eindhoven (MRE) collaboration fund;
	  • Brabantse Ontwikkelings Maatschappij (BOM: regional development organization);
	  • Deeptech XL;
	  • EIT KIC's InnoEnergy, Health, Digital, Urban Mobility and Culture & Creativity

Cultural embedding	• TU/e participates and supports several community initiatives in the ecosystem, such as Brainport voor elkaar (Brainport for each other), Holland Expat Center , Impact 040 and Eindhoven Studentenstad.
International network	• Brainport Development is a member of the European network Vanguard Initiative; • Brainport development undertakes several international projects aimed at open innovation and capacity building; • TU/e is part the EuroTech Universities and EuroTeQ (European universities) network, and the Cluster network; • TU/e participates in several European projects aimed at Open Innovation, such as EIT-projects and ERA-Hub projects.



SOURCE: BART VAN OVERBEEKE

Conclusion

TU/e's adoption of the 4th generation university model shows its dedication to fostering innovation and societal impact. This report highlights the university's achievements and their potential to enable better measures of progress towards the future of higher education.

The quantitative assessment of TU/e's development as a 4th generation university, presented in this report, demonstrates its commitment to fostering innovation, societal development, and economic growth. TU/e excels in several areas, including joint research with industry, dual university–industry appointments, European projects with industry partners, and alignment with key enabling technologies. Its strong performance in these metrics underlines the university's pivotal role in the Brainport Eindhoven ecosystem and beyond.

Despite the challenges in measuring progress towards the 4th generation university model, this report offers an initial attempt at developing a comprehensive framework for capturing additional information about university ecosystem engagements. By examining TU/e's participation in ecosystem leadership, co-creation platforms, partnerships, knowledge infrastructures, capital facilities, cultural embedding, and international networks, we can better understand its contributions to the innovation ecosystem and societal development.

The analysis of TU/e's progress serves as an invitation for further collaboration with technical universities to jointly refine these indicators and measures of progress. By setting a collaborative path for defining how universities can significantly contribute to innovation ecosystems, we can ensure that academic institutions continue to drive forward sustainable and innovative societies, incorporating perspectives from universities across different countries.

In summary, TU/e's commitment to the 4th generation university model has positioned it as a trailblazer in higher education and research. By championing a holistic approach that fosters vibrant local innovation ecosystems, TU/e is playing a crucial role in addressing urgent societal challenges and catalyzing regional economic growth. As universities worldwide continue to evolve and adapt to the changing landscape of higher education, TU/e serves as an inspiring example of the transformative potential of the 4th generation university model.

Acknowledgements

Sponsors

Elsevier

Judy Verses & Nick Fowler

TU/e

Robert-Jan Smits

Report authors

Elsevier

Dmitrii Malkov

Max Dumoulin

TU/e

Renee Westenbrink

Project team

Elsevier

Andrew Plume

Dmitrii Malkov

Elisabeth Browning

Guillaume Roberge

Henrique Pinheiro

Jeroen Baas

M'hamed Aisati

Max Dumoulin

Nick Fowler

Rosetta Federica

TU/e

Christian Staupe

Clément Goossens

Marcel Bogers

Renee Westenbrink

Rianne van Eerd

Robert-Jan Smits

Xavier Theunissen

Dealroom

Aliaksei Vincho

Louis Geoffroy Terryn

Yoram Wijngaarde

Photography

Front cover: Bart van Overbeke

Back cover: Jacob / Adobe Stock

Design

BVDT

Bart van den Tooren

For media inquiries, please contact:

Elsevier: press@elsevier.com, Phone: +31 20 485 3919

Eindhoven University of Technology (TU/e): press@tue.nl, Phone: +31 40 247 4747

Annex

Key Dutch technology families and constituent technologies

Technology family	Technology
Advanced materials	1. Energy materials
	2. Optical, electronic, magnetic and nanomechanical materials
	3. Meta materials
	4. Soft/bio materials
	5. Thin films and coatings
	6. Construction and structural materials
	7. Smart materials
Photonics and optical technologies	1. Photovoltaics
	2. Optical systems and integrated photonics
	3. Photonic/Optical detection and processing
	4. Photon generation technologies
Quantum technologies	1. Quantum computing
	2. Quantum communications
	3. Quantum Sensing
Digital and information technologies	1. Artificial intelligence
	2. Data science, data analytics and data spaces
	3. Cyber security technologies
	4. Software technologies and computing
	5. Digital Connectivity Technologies
	6. Digital Twinning and Immersive technologies
	7. Neuromorphic technologies
Chemical technologies	1. (Bio)Process technology, including process intensification
	2. (Advanced) Reactor engineering
	3. Separation technology
	4. Catalysis
	5. Analytical technologies
	6. Electricity-driven chemical reaction technologies
Nanotechnology	1. Nanomanufacturing
	2. Nanomaterials
	3. Functional devices and structures (on nanoscale)
	4. Micro- and nanofluidics
	5. Nanobiotechnology / Bionanotechnology
Life sciences and biotechnologies	1. Biomolecular and cell technologies
	2. Biosystems and organoids
	3. Biomanufacturing and bioprocessing
	4. Bioinformatics
Engineering and manufacturing technologies	1. Sensor and actuator technologies
	2. Imaging technologies
	3. Mechatronics and opto-mechatronics
	4. Additive manufacturing
	5. Robotics
	6. Digital manufacturing technologies
	7. Micro electronics
	8. Systems engineering

ELSEVIER

Analytical Services