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Factors for Successful Technology Transfer in Deep Tech Ecosystems

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Abstract: Deep Tech ecosystems are increasingly recognized as engines of economic growth, industrial transformation and societal problem-solving. Within these ecosystems, technology transfer is essential for turning scientific discoveries into market-ready innovations. Yet research on drivers of technology transfer in Deep Tech settings is still limited and scattered across disciplines. This systematic literature review synthesizes the available evidence to provide an overview of the factors that shape Deep Tech transfer and provides a guiding framework for ecosystem actors, while highlighting significant gaps in the existing literature. Following a PRISMA-based and AI-supported review protocol, we identify organizational, relational, and technological conditions that support the commercialization of Deep Tech. The findings highlight the importance of combining strong scientific expertise with entrepreneurial skills, access to advanced technical infrastructure, and robust linkages between industry, academia, and government. Therefore, this review offers valuable guidance for leaders and stakeholders seeking to design, govern, and scale Deep Tech ecosystems.

Keywords: Deep Tech, Deep Tech ecosystems, innovation ecosystems, technology transfer, success factors, triple helix, university-industry collaboration, systematic literature review, commercialization

1 Introduction

Technological progress is well-understood to be a central driver of economic growth and societal progress. In recent years, a new wave of technologies has become the centre of awareness when it comes to technological advancement. Deep technologies, or more often referred to as Deep Tech, are considered to be a main driver for solving societal and environmental problems (Nedayvoda et al., 2021).

While expectations for Deep Tech are high, many technologies fail to progress beyond the basic research stage leading to an estimated 90% of Deep Tech Startups to fail. The transfer of Deep Tech from research to market is particularly challenging as it combines significant technological and financial risks and requires specialized infrastructure as well as long-term commitment from stakeholders (Romme et al., 2023). In this context, well-functioning innovation ecosystems become crucial to support the technology transfer of such innovations. Within these ecosystems various actors, like universities, industry and government, cooperate with the purpose of transforming research and development (R&D) output into market-ready innovations (Leydesdorff and Etzkowitz, 1998, Jackson, 2011).

Innovation ecosystems, as well as technology transfer, have both been the subject of extensive research. In the context of Deep Tech, however, these insights remain scattered across disciplines and context. As a result, the mechanisms driving technology transfer in Deep Tech ecosystems are not yet integrated into a coherent body of knowledge.

Understanding these mechanisms is particularly important for all actors involved in building, shaping or participating in Deep Tech ecosystems, as resource allocation and strategic alignment can support the successful transition of Deep Tech from research to market.

Therefore, this work focuses on the following research question: *What factors enable successful technology transfer in Deep Tech ecosystems?* This paper will begin by introducing the relevant terms based on the current state of knowledge in literature. This is followed by description of the methodology used for the systematic literature review. Afterwards, results will be presented. Building on these findings, we introduce a theoretical and actor-based framework for successful technology transfer in Deep Tech ecosystems.

2 Background

Deep Tech

Deep Tech refers to innovations that are rooted in scientific or engineering breakthroughs often in the fields of artificial intelligence, quantum computing, life science and biotechnology, advanced materials or clean mobility. In contrast to traditional technology or “high-tech”, Deep Tech has the potential to reshape industries and establish new standards in a field or even society in general (Peña and Jenik, 2023, UNDP, 2025).

Due to its potential high impact, Deep Tech is regarded as an important instrument for building wealth and ensuring technological sovereignty (McKinsey & Company, 2025, Schuh et al., 2022a). Moreover, almost all Deep Tech innovations address at least

one of the 17 Sustainable Development Goals (SDGs) of the United Nations (Gourevitch et al., 2021), thereby combining economic and strategic motivation with idealistic purposes by addressing global challenges like climate change or health (Kowal and Przewoźnik, 2025). As technological progress advances and global challenges and social needs demand direct strategic focus, main focus areas of Deep Tech innovations have changed over time, ranging from defence and nuclear research in the 1960s, over telecommunication innovation like the internet in the late 1990s, while today Deep Tech focuses on artificial intelligence, medtech and climate change remission (Kowal and Przewoźnik, 2025).

From a technology perspective, Deep Tech is defined by high R&D costs, long time to market and a significant technological and market risk (de Apodaca et al., 2023, Schuh et al., 2022a). Due to the novelty of these technologies, their technological feasibility often remains uncertain, while a clear market demand may not yet exist (Schuh et al., 2022b).

Technology Transfer

Technology transfer describes the process of moving a new technology from the R&D stage to a recipient, usually a private company, with the ultimate goal of enabling its commercial application (Rogers et al., 2001). It is generally accomplished through mechanisms such as intellectual property (IP) management, co-development partnerships, research spin-offs, research contracts for specific projects and non-commercial transfer through free sharing of resources (de Assunção et al., 2024, Chen et al., 2022). Technologies can reach the market through several commercialization pathways, including startup formation and industry licensing, selected according to factors such as market opportunity, operational risk, and expected return on investment (Kruachottikul et al., 2023).

There are different approaches in describing the stages of the transfer process. For example Gibson and Sung (2003) define four levels of technology transfer to be Creation, Sharing, Implementation and Commercialization (Gibson and Sung, 2003). A more recent model describes five stages of technology transfer to be identifying, assessing, protecting, promoting, and profiting (Chen et al., 2025). While these two models identify research findings as the initial trigger, other models define an industrial problem or need as the initiator of research and the subsequent transfer process (Gorschek et al., 2006).

However, there is no consensus in the literature on how to define or measure successful technology transfer, as it may be assessed through the number of patents or licenses, financial indicators, or broader societal impact, among others (López-Mendoza and Mauricio, 2021).

Innovation Ecosystems

According to Jackson (2011) an innovation ecosystem is the complex interplay of actors and entities that together pursue the goal of technology development and innovation and in particular bridging the gap between research and market (Jackson, 2011). A more specific definition describes innovation ecosystems as “networks of companies, universities, government organizations, and other stakeholders that work together to

promote entrepreneurship, innovation, and economic development" (Sotirofski, 2024, Ding and Wu, 2017). Within this ecosystem the most prominent actors, academia, industry and government are often referred to as "Triple Helix". In this model academia serves as the knowledge and technology generator, industry supports commercialization and dissemination processes, while the government promotes and regulates innovation, making all three actors essential for successful technology transfer (Etzkowitz, 2003).

While there is a robust conceptual understanding of innovation ecosystems in the literature, there is little to no definition of the term "Deep Tech ecosystem", even though it is frequently used in policy documents, consulting reports and research articles, which mostly put it in the context on an innovation ecosystem for Deep Tech startups, defined by Deep Tech characteristics, like high capital intensity and long development cycle. Romasanta et al. (2021) regard the term "ecosystem" rather as an perspective in the context of Deep Tech, while Kowal and Przewoźnik (2025) describe Deep Tech ecosystems as "a complex organism that connects various stakeholder groups" which relies on good collaboration and knowledge and experience exchange (Kowal and Przewoźnik, 2025, Romasanta et al., 2021). In their report, de la Tour et al. (2019) describe Deep Tech ecosystems to involve a diverse set of actors, characterized by high dynamism and multifaceted collaboration in which exchanges extend beyond funding to include knowledge, skills, and networks (de la Tour et al., 2019). Besides the Triple Helix actors and startups, important stakeholders participating in Deep Tech ecosystems are incubators and accelerators, venture capitalists and business angels, customers and media (UNDP, 2025).

For the purpose of this study, we therefore propose the following definition of a Deep Tech ecosystem:

> "A Deep Tech ecosystem is a subtype of an innovation ecosystem characterized by the dynamic interplay of a diverse set of actors, who collaborate to advance science-based, capital-intensive technologies with long development cycles and high technological risks, through multifaceted exchanges of knowledge, skills, networks, resources and funding."

3 Methods

The aim of this work is to qualitatively identify success factors for technology transfer in Deep Tech ecosystems via a systematic literature review. The study identification and selection process was guided by the approach recommended by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) and the corresponding flow diagram was used to document the screening process (Page et al., 2021). Other reporting components of the guideline were adapted or omitted in accordance with the purpose of this study.

As Deep Tech is a relatively new and heterogeneously described research area, we followed a mixed search strategy, that combined searches in established academic databases with AI-assisted literature retrieval. Thereby, we ensured to also identify Deep Tech-relevant studies that might otherwise be overlooked due to inconsistent terminology not captured by standardized keywords.

Database search was conducted using the Web of Science Core Collection (WoS) and IEEE Xplore. Both databases were screened using the same combination of keywords. To mitigate the heterogeneous terminology associated with Deep Tech, the search strategy included not only variations of the term “Deep Tech” but also terms representing specific Deep Tech domains.

Accordingly, for WoS the following search term was used: *TS=("deep tech" OR "deep technolog*" OR “deeptech” OR "hard technolog*" OR "hard tech" OR "frontier technolog*" OR "advanced manufacturing" OR "advanced material*" OR "artificial intelligence" OR biotechnolog* OR "life science*" OR microelectronics OR robotics OR "quantum technolog*") AND TS=("technology transfer" OR "tech transfer" OR "research transfer" OR "knowledge transfer" OR “commerciali*ation” OR "academic entrepreneurship" OR "spin-off") AND TS=("innovation ecosystem" OR "entrepreneurial ecosystem" OR "innovation system" OR "innovation environment" OR "triple helix" OR "deep tech ecosystem")*

IEEE Xplore was searched via the following term: *("All Metadata":"deep tech" OR "All Metadata":"deep technolog*" OR "All Metadata":”deeptech” OR "All Metadata":"hard technolog*" OR "All Metadata":"hard tech" OR "All Metadata":"frontier technolog*" OR "All Metadata":"advanced manufacturing" OR "All Metadata":"advanced material*" OR "All Metadata":"artificial intelligence" OR "All Metadata":”biotechnolog*” OR "All Metadata":"life science*" OR "All Metadata":”microelectronics” OR "All Metadata":”robotics” OR "All Metadata":"quantum technolog*") AND ("All Metadata":"technology transfer" OR "All Metadata":"tech transfer" OR "All Metadata":"research transfer" OR "All Metadata":"knowledge transfer" OR "All Metadata":”commerciali*ation” OR "All Metadata":"academic entrepreneurship" OR "All Metadata":"spin-off") AND ("All Metadata":"innovation ecosystem" OR "All Metadata":"entrepreneurial ecosystem" OR "All Metadata":"innovation system" OR "All Metadata":"innovation environment" OR "All Metadata":"triple helix" OR "All Metadata":"deep tech ecosystem")*

The AI-assisted identification of papers was carried out using the “Find papers” tool provided by *Elicit* (Elicit). This tool retrieves scientific publications that are relevant to a user-defined research question. For this purpose, the central research question of this study was used as the prompt: *“What factors enable successful technology transfer in Deep Tech ecosystems?”.* Given the ranked nature of AI-assisted search, we extracted the top 50 Elicit results.

Combining the database and the AI-assisted search strategy, a total of 167 studies were identified. After removal of duplicates, the titles and abstracts of the remaining papers were screened and assessed for relevance to the research question. Afterwards, the full texts of the relevant papers were reviewed and evaluated regarding their relevance. Only research articles in English were included. Articles without available full text were excluded. Ultimately, this search strategy resulted in 17 studies that met the inclusion criteria (Figure 1).

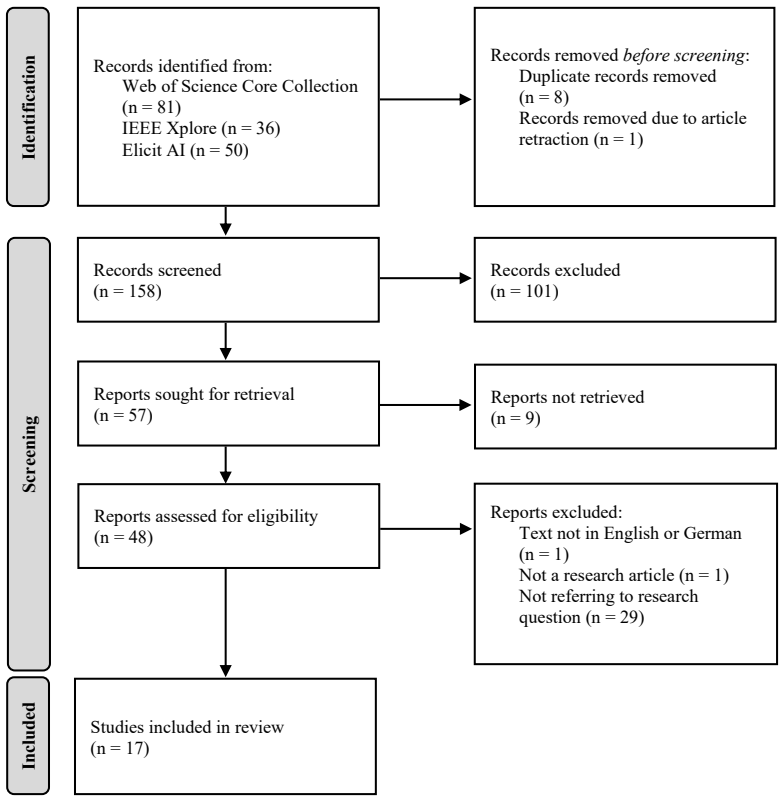

Figure 1 PRISMA-based Search Strategy.

The final set of studies was analyzed with a focus on success factors as outcomes. For the purpose of this review, we synthesized only those success factors that are explicitly and positively framed in the original article, and do not convert barriers or challenges into hypothetical success factors. The identified success factors were then systematically examined by clustering similar statements into thematic phrases, which were then organized into higher-level, ecosystem-oriented categories.

Based on the set of identified success factors, we subsequently developed an actor-based framework. The framework maps success factors to the ecosystem participants, illustrating how different stakeholders each play a role in enabling effective technology transfer in Deep Tech ecosystems.

4 Results

To provide an overview of the existing research landscape, the publication counts for each search-term category are depicted in Figure 2 based on the previously defined search terms applied to WoS and IEEE Xplore. The findings reveal that while each

individual category is represented by a substantial number of publications, only a small fraction of articles simultaneously addresses all three topics. This imbalance highlights a notable research gap at the intersection of Deep Tech, technology transfer, and innovation ecosystems.

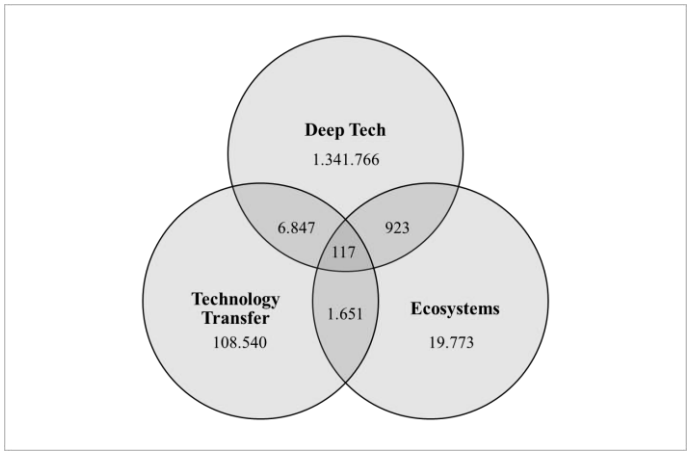

Figure 2 Number of Publications Identified per Search Term.

Systematic Literature Review

The identification and screening process for the systematic literature review yielded a final set of 17 papers addressing the research question of this work. The studies found in this systematic review were published between 2007 and 2025, with a notable increase of publications from 2022 onwards. Although the limited sample size does not allow statistical conclusions, the temporal distribution of the identified studies indicates a growing research interest in Deep Tech transfer mechanisms within innovation ecosystems in recent years. Four of the identified papers focus on Deep Tech as a general concept, while two articles focused on ecosystems of two Deep Tech domains and eleven studies are referring to ecosystems of specific Deep Tech domains, most notably focusing on the life science sector. The set of studies shows heterogeneous methodological approaches, applying case studies, interviews and reviews.

Identified success factors

From the articles analyzed, a total of 65 success factors for technology transfer in Deep Tech ecosystems were identified (Table 1). These success factors were organized into a hierarchical set of 9 categories spanning system-level, organizational, and actor-level dimensions.

Governance, Policy & Regulation refers to national and regional policy frameworks, regulatory conditions, and public-sector support shaping the overall environment for Deep Tech transfer. *Financial Resources & Funding* captures the availability of financial

instruments, including early-stage capital, regional and external funding, and venture investment. *Regional Ecosystems & Networks* comprises factors of collaboration structures, interaction channels and multi-actor networks that facilitate knowledge and technology transfer. *Universities & Research Institutions* describes roles, capacity and culture within institutions of knowledge generation that contribute to transfer activities. *Industry factors* covers firms' absorptive capacity and organizational capabilities. *Institutional & Organizational Support* includes regional institutions and programs like intermediaries, incubators, accelerators, technology transfer offices (TTOs) and their actions that support the transfer process. *Knowledge & Technology Factors* relates to ecosystem activities and conditions promoting the transferability of technologies as well as innovation practices. *Application Environment & Real-World Integration* refers to infrastructural and organizational conditions for practical validation of technologies. *Human Capital & Talent* comprises skills, expertise mindset of individuals involved in transfer processes.

Table 1 Success Factors for Technology Transfer in Deep Tech Ecosystems.

Category	*Success Factor*	*Source*
Governance, Policy & Regulation	Balanced Triple Helix structure	(Wong, 2007)
	IP strategy, support and tools	(Kruachottikul et al., 2023), (Alkhazaleh et al., 2022), (Nowicki, 2017), (Mehra and Joshi, 2010), (Casper and West, 2024)
	Proactive public sector and legal support throughout the whole process	(Alkhazaleh et al., 2022), (Chen and Lin, 2017), (Mehra and Joshi, 2010)
	Recognition of technology relevance	(Mehra and Joshi, 2010)
	Regional identity	(Romme, 2022)
	Risk-tolerant regulation	(Kowal and Przewoźnik, 2025)
	Triple Helix role flexibility	(Liboreiro et al., 2022)
	Well-balanced regional governance	(Romme, 2022)
Financial Resources & Funding	Availability of venture capital	(Casper and West, 2024)
	Deep Tech-specific capital	(Wong, 2007)
	Early-stage private capital (angel & university-related funds)	(Casper and West, 2024)
	Funding from outside the region	(Casper and West, 2024)
	Funding for infrastructure development	(Mehra and Joshi, 2010)
	National/ EU funding	(Chiș and Crișan, 2020), (Kowal and Przewoźnik, 2025), (Chen and Lin, 2017), (Mehra and Joshi, 2010), (Liboreiro et al., 2022), (Umemura, 2025)
Regional Ecosystem & Networks	Bi-directional knowledge exchanges	(Chen and Lin, 2017)
	Co-location of R&D and business incubation e.g. in innovation hubs	(Romme, 2022) (Liboreiro et al., 2022)

	Consistent interaction channels (spin-off pathways and partnerships)	(Liboreiro et al., 2022)
	Continuous interaction with technology adopters, also after transfer	(Chiș and Crișan, 2020) (Mehra and Joshi, 2010)
	Early knowledge exchange and collaboration between institutions (pre-patent)	(Alkhazaleh et al., 2022), (Chen and Lin, 2017)
	Historical or contextual advantages	(Romme, 2022), (Umemura, 2025)
	Incentives for university-industry interaction	(Liboreiro et al., 2022)
	Inter- or multidisciplinary environment	(Romme, 2022), (Alkhazaleh et al., 2022), (Wong, 2007)
	Involvement and network of technological and entrepreneurial experts (mentors, advisors, alumni)	(Kruachottikul et al., 2023), (Wong, 2007), (Mehra and Joshi, 2010)
	Multi-actor collaboration	(Wong, 2007)
	Network for funding	(Meyer et al., 2024)
	Network of start-ups	(Meyer et al., 2024)
	Strong collaboration between university, industry and government	(Chiș and Crișan, 2020), (Romme, 2022), (Kruachottikul et al., 2023), (Meyer et al., 2024), (Alkhazaleh et al., 2022), (Nowicki, 2017), (Mehra and Joshi, 2010), (Umemura, 2025)
	Technical and Scientific Services as knowledge bridges between research and industry	(Chiaroni et al., 2008)
	University embeddedness in ecosystems	(Meyer et al., 2024), (Xia et al., 2025)
Universities & Research Institutions	Entrepreneurship education and programs across all disciplines	(Kowal and Przewoźnik, 2025), (Wong, 2007), (Umemura, 2025), (Casper and West, 2024)
	Generation of knowledge and technologies	(Chen and Lin, 2017)
	Inventor-friendly, entrepreneurial culture	(Wong, 2007)
	Involvement of universities as key actors for commercialization	(Alkhazaleh et al., 2022), (Xia et al., 2025), (Chen and Lin, 2017)
Industry Factors	Ability to absorb external knowledge	(Chiș and Crișan, 2020), (Xia et al., 2025), (Chen and Lin, 2017)
	Demand-driven pull from industry	(Nowicki, 2017)
	Trained staff, strategy, collaboration culture, knowledge management	(Alkhazaleh et al., 2022), (Xia et al., 2025)
Institutional & Organizational Support	Access to research infrastructure (labs, specialized equipment, samples)	(Chiș and Crișan, 2020), (Meyer et al., 2024), (Liboreiro et al., 2022)

	Commercialization support	(Wong, 2007)
	Hands-on incubators and accelerators with clear incubation methodology	(Kowal and Przewoźnik, 2025), (Kruachottikul et al., 2023), (Meyer et al., 2024), (Casper and West, 2024)
	Hybrid & Intermediary Organizations facilitating cooperation and transfer	(Linton, 2024), (Mehra and Joshi, 2010)
	Incentive systems for commercialization	(Alkhazaleh et al., 2022)
	Infrastructure connecting academia & industry	(Mehra and Joshi, 2010)
	Interdisciplinary transfer centers	(Kowal and Przewoźnik, 2025), (Alkhazaleh et al., 2022)
	Legal support	(Kruachottikul et al., 2023)
	Matching technology to available capacities	(Wong, 2007)
	Programs for linking scientists with entrepreneurship community	(Casper and West, 2024)
	TTOs as mediators matching academia & industry	(Nowicki, 2017), (Chen and Lin, 2017), (Liboreiro et al., 2022), (Casper and West, 2024)
	Well-defined innovation process and organizational structure	(Nowicki, 2017)
Knowledge & Technology Factors	Early technology-market matching	(Park et al., 2024)
	Open innovation practices	(Alkhazaleh et al., 2022)
	Pre-formation assets (patents, research excellence, international networks)	(Park et al., 2024)
	Product- & commercial-oriented innovation	(Chen and Lin, 2017)
	Technological push, research output	(Nowicki, 2017)
Application Environment & Real-World Integration	Access to specialized pilot-scale production facilities	(Mehra and Joshi, 2010)
	Early user trials and market testing	(Kruachottikul et al., 2023)
	Proximity and access to testing infrastructure and application sites e.g. hospitals or companies	(Wong, 2007), (Chen and Lin, 2017), (Umemura, 2025)
Human Capital & Talent	Competent TTO employees	(Alkhazaleh et al., 2022)
	Combination of business and technical expertise	(Kruachottikul et al., 2023), (Nowicki, 2017)
	Diversity of talent (multidisciplinary and international)	(Liboreiro et al., 2022), (Umemura, 2025)
	Entrepreneurial mindset	(Meyer et al., 2024), (Chen and Lin, 2017), (Mehra and Joshi, 2010), (Park et al., 2024)
	Human capital development & creativity support	(Chiș and Crișan, 2020)

Individual champions and star scientists	(Mehra and Joshi, 2010), (Umemura, 2025), (Casper and West, 2024)
Involvement and network of technological and entrepreneurial experts (mentors, advisors, alumni)	(Chiș and Crișan, 2020), (Kowal and Przewoźnik, 2025), (Meyer et al., 2024), (Nowicki, 2017), (Mehra and Joshi, 2010), (Park et al., 2024)
IP education	(Liboreiro et al., 2022)
Leadership support	(Chiș and Crișan, 2020)

The identified success factors reveal that technology transfer within Deep Tech ecosystems relies on coordinated system-level conditions, multi-sourced financial and organizational support, as well as a strong connectivity and collaboration between ecosystem actors. Universities emerge as a central player which serve as the primary source of technology and knowledge while at the same time, they are actively promoting transfer processes. Industry partners contribute through high absorptive capacities and demand driven ecosystems collaboration. The findings also highlight the importance of balanced and adequate governance arrangements, interdisciplinary networks combining technical and entrepreneurial expertise and strategic and hands-on intermediary organizations, like TTOs and incubators, that promote collaboration and knowledge exchange. Moreover, the results strongly suggest that technology transfer does not only rely on institutional efforts but also on skilled, well-connected and motivated individuals participating in transfer processes within Deep Tech ecosystems, as twelve of the studies suggested a positive impact of human capital on Deep Tech transfer. With focus on Deep Tech characteristics this might not only include sensitization for commercialization activities but also encouragement of risk-taking, long-term thinking and interdisciplinary collaboration.

Framework

Based on our review, an actor-specific framework for successful technology transfer in Deep Tech ecosystems is introduced (Figure 3). The framework derives the underlying conditions and recommended actions from the identified success factors and structures them by distinct actor groups. The model does not aim to be exhaustive in terms of actors and conditions, as it is solely grounded in the findings of the review.

Government & Public Sector. An essential role of the government and public sector in Deep Tech transfer is the provision of funding. Such funding is not only intended to support the technology transfer process itself but also to enable the development of infrastructure that is critical for transfer activities. Moreover, the government and public sector can reinforce technology transfer through the enactment of strategic and transfer-supportive legislation, as well as through the implementation of incentives that promote commercialization activities. This also includes the establishment of regulations that allow technological experimentation (Kowal and Przewoźnik, 2025), for example in the format of regulatory sandboxes or living labs. Lastly, the government, as an actor in the Triple Helix structure, needs to enable role flexibility within this triad (Liboreiro et al., 2022).

Universities. Universities take a central role in Deep Tech ecosystems. Besides the generation of knowledge, they provide access to research facilities and networks of knowledges exchange (Meyer et al., 2024, Xia et al., 2025). When it comes to technology transfer capabilities, it is crucial for universities to provide entrepreneurship training across faculties and disciplines and to establish a multidisciplinary environment (Kowal and Przewoźnik, 2025, Wong, 2007, Umemura, 2025, Casper and West, 2024). Additionally, universities shall sensitize scientists for commercialization and encourage them to pursue a transfer-related pathway (Kowal and Przewoźnik, 2025). This goes along with the establishment of IP training and support (Liboreiro et al., 2022) as well as an "inventor friendly" licensing strategy with an increased focus on deployment and practical utilization of university technologies instead only focusing on maximizing revenue (Wong, 2007). Further, universities can support Deep Tech transfer by setting up TTOs, which can serve as mediators between the university and industry and help to accelerate transfer (Liboreiro et al., 2022, Nowicki, 2017, Chen and Lin, 2017, Casper and West, 2024).

Investors. Venture capitalists, business angels and university related funds support technology transfer by funding research and transfer activities. For Deep Tech, private capital can support transfer by specifically addressing early development stages and specific technologies or sectors (Casper and West, 2024, Umemura, 2025, Wong, 2007). Additionally, investors can support transfer and commercialization of Deep Tech by functioning as experts and mentors (Wong, 2007).

Industry. As a technology recipient, industry can particularly support Deep Tech transfer by engaging in collaborations with universities and research institutions in a pre-patent stage to acquire knowledge in an early phase of R&D (Chen and Lin, 2017, Alkhazaleh et al., 2022). Also, industry fuels technology transfer by creating technology pull (Nowicki, 2017). Integration of external knowledge into companies must be promoted by building absorptive capacities within the firm to enable adequate adoption of external knowledge (Xia et al., 2025, Chiș and Crișan, 2020) which can happen via a clear strategy, collaborative culture, staff education and training as well as adequate knowledge management practices (Xia et al., 2025, Alkhazaleh et al., 2022). Industry can further support Deep Tech transfer by providing access to testing infrastructure and facilities for pilot scale production (Mehra and Joshi, 2010, Wong, 2007, Chen and Lin, 2017, Umemura, 2025).

Intermediaries. Intermediaries function as mediators between actors of technology transfer while being an ecosystem actor themselves. Their central role in promoting Deep Tech transfer is to foster collaboration between universities and industries, especially at an early stage (Linton, 2024, Casper and West, 2024, Chiaroni et al., 2008). Further, their role is to create a multidisciplinary environment by combining technological and entrepreneurial expertise in teams (Meyer et al., 2024). Another important role of intermediaries in promoting Deep Tech transfer is the establishment of strong networks of experts, collaborators and investors (Meyer et al., 2024, Wong, 2007, Linton, 2024, Kruachottikul et al., 2023). Additionally, intermediaries can drive technology transfer by providing support in legal, IP and commercialization matters (Wong, 2007, Kruachottikul et al., 2023, Meyer et al., 2024).

Cross-Actor Conditions. There are also conditions that support Deep Tech transfer and apply to several or even all actors within the ecosystem. For example, the co-location of research institutions, industry partners, business incubation and intermediaries within innovation hubs can strengthen collaboration and facilitate more effective transfer activities (Romme, 2022). Proximity among these actors, application sites and testing infrastructure should therefore be considered when designing and building ecosystems (Umemura, 2025, Romme, 2022, Wong, 2007). Also, the importance of a strong and collaborative network across all ecosystem participants is regarded an existential driver

for Deep Tech transfer and should therefore be encouraged by all ecosystem participants (Meyer et al., 2024, Kruachottikul et al., 2023, Wong, 2007, Mehra and Joshi, 2010, Park et al., 2024, Chiș and Crișan, 2020).

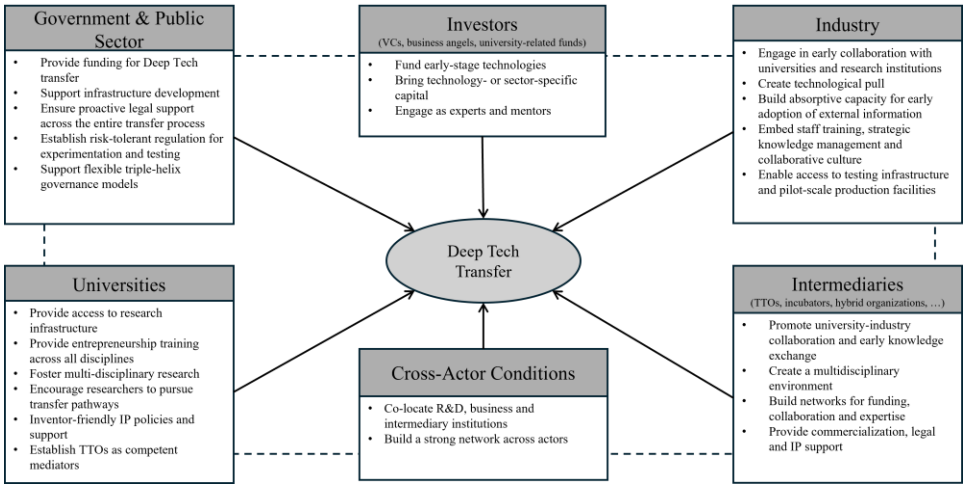

Figure 3 Framework for Technology Transfer in Deep Tech Ecosystems.

5 Discussion

Deep Tech ecosystems are increasingly recognized as a critical engine for addressing societal and environmental challenges. However, the academic literature on Deep Tech ecosystems and drivers for technology transfer remains limited and fragmented across different contexts. Existing studies often focus on isolated domains and technologies, resulting in a lack of a comprehensive understanding of what drives Deep Tech innovation in a more general context. To overcome this gap, our study synthesises success factors for technology transfer in Deep Tech ecosystems. By integrating different Deep Tech-related search terms into the database search and combining this classical approach with AI-based literature retrieval, we mitigated the inherent heterogeneity of the Deep Tech literature. We decided to use Elicit as an AI tool, as it has been shown to be a valuable complementary tool in systematic reviews (Bernard et al., 2025) and allows identification of relevant studies beyond the conventional database search. This combined search strategy allowed us to identify a more comprehensive set of publications that better reflects diverse technologies, ecosystems and sectors relevant to Deep Tech than traditional database search strategies alone. Based on the identified success factors of this systematic literature review, we developed a framework for successful technology transfer in Deep Tech ecosystems that incorporates the actors identified in the reviewed studies and translates the success factors into actionable elements. Thereby, we provide literature-based guidance for ecosystems actors and orchestrators. However, it is worth noting, that due to the previously mentioned limited literature on this topic, we do not regard this framework as fully exhaustive with respect to the success factors and stakeholders. While most of the identified studies for example focused on universities as

sources of knowledge and technology, many of the success factors might also apply to other research institutions.

Across the 17 articles included, we found a total of 65 factors that were assigned to nine categories. Our findings show that technology transfer in Deep Tech ecosystems is a multi-dimensional process depending on organisational, institutional and relational conditions. The results underscore that Deep Tech transfer is not driven by the actions of single entities but depends on the engagement of multiple actors within the ecosystem.

Among the identified factors, the most prominent success factor related to a strong and sustained collaboration between academia, industry and government. Given the extensive amount of research already investigating the Triple Helix model and university-industry relations, our findings align with the literature. However, there are models considering the Triple Helix approach to be insufficient for describing innovation systems and establish, for example, a "Quadruple Helix" model, including society as a stakeholder (Carayannis and Campbell, 2009) or a "Quintuple Helix" model, additionally including sustainability and environmental dimensions as drivers for innovation (Carayannis et al., 2012). Interestingly, even though these models do not specifically address Deep Tech, it is worth noting that none of the 17 identified studies in this systematic literature review mentioned an impact of society or sustainability factors on Deep Tech transfer, even though Deep Tech specifically addresses social and environmental challenges. Also, none of the identified studies mentioned adaptation to change and product satisfaction to be a driver for technology transfer in Deep Tech ecosystems, which have been found to be important success factors in traditional innovation ecosystems (López-Mendoza and Mauricio, 2021). However, it cannot be said whether these factors are missing due to limited empirical evidence, a narrow research focus, or their genuinely minor role in Deep Tech technology transfer. It may also reflect the early stage of Deep Tech research, where priorities concentrate rather on technical feasibility instead of societal and ecologic factors.

The present study and the applied search strategy, however, bring some limitations. Firstly, as noted before, the term Deep Tech is used inconsistently across regions and context, and is gaining popularity only in the recent years. Hence, it is possible that some relevant studies referring to Deep Tech were not captured by our search strategy. Moreover, the inclusion of specific Deep Tech domains can lead to a domain-specific bias. Many of the studies identified within this work were referring to the life science and biotechnology sector, suggesting that these fields might already be more prominently represented in the literature. As a result, success factors applying to these Deep Tech areas might be overrepresented and can not necessarily be transferred to all other areas. Also, we only included search terms and studies that were in English. It is possible, that relevant studies in other languages were missed. This is particularly relevant, as innovation ecosystems generally are a rather regional topic, which might be described in the respective regional language. Lastly, our study focused exclusively on research articles. Deep Tech and emerging technologies are frequently addressed in whitepapers, industry reports, and publications by consulting firms or professional associations, which may include important success factors for technology transfer in Deep Tech ecosystems that did not appear in research publications.

Accordingly, future studies could focus on success factors identified in the grey literature as well as non-English sources and integrate them with the present findings to develop a more comprehensive and practice-oriented understanding of Deep Tech ecosystem dynamics. There is also a need for ecosystem- and technology transfer-related

research in Deep Tech areas that have so far receive little attention, such as artificial intelligence or advanced materials. Over the long term, it would be valuable to investigate how success factors differ across technological fields and regional contexts.

6 Conclusion

The present work shows, that although Deep Tech is increasingly viewed as strategically important, the existing research base remains fragmented and can yet only offer a limited understanding of what drives technology transfer in Deep Tech ecosystems. Our study reduces fragmentation by synthesizing research from different contexts and sources, therefore not only extending the knowledge on important success factors for Deep Tech transfer but also demonstrating the value of a hybrid methodology for emerging research fields. Our research shows, that Deep Tech transfer and ecosystems are multidimensional and driven by the coordinated actions of multiple stakeholders. The resulting framework translates these factors into actionable elements, thereby offering an initial guidance for policymakers and ecosystem participants. Future research should investigate non-academic sources and underexplored Deep Tech domains to build a more comprehensive understanding of what drives successful technology transfer in Deep Tech ecosystems.

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